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Applications Analysis Report
Soliditech, Inc. Solidification/ Stabilization Process

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

Notice

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Foreword

The Superfund Innovative Technology Evaluation (SITE) program is a joint effort **between** EPA's Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER). The purpose of the program is to assist the development of hazardous waste treatment technologies necessary to meet new, more permanent cleanup standards. The SITE program includes technology demonstrations to provide engineering and cost data on selected technologies.

A field demonstration was conducted under the SITE program to evaluate the Soliditech, Inc. solidification/stabilization technology. The technology demonstration took place at a Superfund site in Morganville, New Jersey. The demonstration provided information on the performance and cost of the technology for use in assessing its applicability to this as well as other uncontrolled hazardous waste sites. The demonstration is documented in two reports: (1) a Technology Evaluation Report that describes the field activities and laboratory results; and (2) this Applications Analysis Report, which interprets the data and discusses the potential applicability of the technology.

A limited number of copies of this report will be available at no charge from EPA's Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, Ohio 45268. Requests should include the EPA document number found on the report's front cover. When the limited supply is exhausted, additional copies can be purchased from the National Technical Information Service, Ravensworth Bldg., Springfield, Virginia, 22161, (703) 487-4600. Reference copies will be available at EPA libraries in the Hazardous Waste Collection. Call the SITE Clearinghouse hotline at 1-800-424-9346 or 382-3000 in Washington, D.C., to inquire about the availability of other reports.

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Abstract

This Applications Analysis Report evaluates the Soliditech, Inc., solidification/ stabilization process for the on-site treatment of waste materials. The Soliditech process mixes and chemically treats waste material with Urrichem (a proprietary reagent), additives, pozzolanic materials or cement, and water, in a ten-cubic yard concrete mixer to form a more stable material.

The Soliditech demonstration took place in December 1988 at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey. Three types of contamination waste material were chosen for this demonstration -- contaminated soil, waste filter cake material, and oily sludge from an abandoned storage tank. The wastes contain PCBs, various metals, and petroleum hydrocarbons. Extensive sampling and analyses were performed on the waste materials both before and after treatment so that physical, chemical, and leaching properties could be compared.

The Soliditech process was evaluated based on contaminant mobility, measured by leaching and permeability tests; structural integrity of the solidified material, measured by physical, engineering, and morphological tests; and economic analysis, using cost information supplied by Soliditech, Inc. and supplemented by additional information generated during the demonstration.

The conclusions drawn from these evaluations are that: (1) the Soliditech process can solidify waste materials containing high oil and grease concentrations; (2) heavy metals such as arsenic, cadmium, lead, and zinc are successfully immobilized; (3) the short-term physical stability of the treated waste was good, with significant unconfined compressive strength and low permeability; (4) long-term testing of the treated wastes indicates a potential for physical degradation, as evidenced by reduced unconfined compressive strength after 12 cycles of wet/dry and freeze/thaw testing as well as crack and fissure development on the treated wastes after 6 months of storage; (5) treatment results in a volume increase of 0 to 59 percent (22 percent average) and a bulk density increase of 25 to 41 percent (a quantity of cement, reagent, additives and water approximately the weight of the waste was added during treatment); and (6) the process is economical.

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Abbreviations

AA	Atomic Absorption Spectroscopy
ANS 16.1	American Nuclear Society Leaching Procedure
API	American Petroleum Institute
ARARs	applicable or relevant and appropriate requirements
BET	Batch Extraction Test
BDAT	best demonstrated available technology
°C	degrees Celsius
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cm	centimeter
DAF	dissolved air flotation
DOT	Department of Transportation
Eh	oxidation/reduction potential
EP	Extraction Procedure Toxicity Test
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
FR	Federal Register
ft	foot (feet)
gal	gallon
gpd	gallons per day
HDPE	high-density polyethylene
hr	hour(s)
HSWA	Hazardous and Solid Waste Amendments
ICPES	Inductively Coupled Plasma Emission Spectroscopy
Kg	kilogram
L	liter
lb	pound
LDR	Land Disposal Restrictions
mg	milligram
mg/kg	milligram per Kilogram
mg/L	milligram per Liter
mil	thousandth of an inch
mm	millimeter
mo	month
mv	millivolts
NA	not analyzed
NC	not calculated

(continued)

Abbreviations (continued)

NCP	National Contingency Plan
ND	not detected
NJ DEP	New Jersey Department of Environmental Protection
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PCB	polychlorinated biphenyl
pH	negative logarithm of the hydrogen ion activity
ppm	parts per million
PRC	PRC Environmental Management, Inc.
psi	pounds per square inch
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
sec	second
SITE	Superfund Innovative Technology Evaluation
S/L	solid to liquid ratio
SVOC	semivolatile organic compound
SWDA	Solid Waste Disposal Act
TCLP	Toxicity Characteristics Leaching Procedure
TDS	total dissolved solids
TOC	total organic carbon
TSCA	Toxic Substances Control Act
TWM	treated waste monolith
u c s	unconfined compressive strength
VOC	volatile organic compound
WILT	Waste Interface Leaching Test
wk	week
wt	weight
Yd	yard
yr	Year
µg	micrograms
µg/L	micrograms per Liter

Conversion of U.S. Customary Units to Metric Units

Length

inches	x	2.54	=	centimeters
inches	x	0.0254	=	meters
feet	x	0.3048	=	meters

Volume

gallons	x	3.785	=	liters
cubic yards	x	0.7646	=	cubic meters

Weight

pounds	x	0.4536	=	kilograms
short tons	x	0.9072	=	metric tons

Temperature

5/9	x	(° Fahrenheit - 32)	=	° Celsius
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Note:	1000	liters	=	1 cubic meter
	1000	kilograms	=	1 metric ton

Acknowledgments

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Section 1

Executive Summary

Introduction

Soliditech, Inc. of Houston, Texas has developed a unique technology to solidify and stabilize soils and sludges contaminated with inorganic and organic wastes. U.S. EPA selected the Soliditech technology for inclusion in the SITE demonstration program. As a part of this program, the Soliditech technology was demonstrated in December 1988 at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey.

Soliditech, Inc. claims that its solidification/stabilization process chemically and physically immobilizes hazardous constituents in waste material. This immobilization occurs by one or more of the following processes: encapsulation, adsorption, and incorporation into the crystalline structure of the solidified material. The Soliditech process uses a proprietary reagent (Urrichem); proprietary additives; pozzolans (such as fly ash), kiln dust, or cement; and water to solidify solids and sludge containing organic and inorganic chemicals typically found at hazardous waste sites. The final product is claimed to be a monolithic material with measurable structural strength and significantly reduced leaching or extraction potential.

The Soliditech SITE demonstration was conducted during the week of December 5, 1998. Four test runs were performed on three wastes and also on clean sand to serve as an analytical blank for the reagent mixture (Urrichem, proprietary additives, cement, and water). For each test run 2 to 6 cubic yards of material were treated. The three wastes were contaminated soil, waste filter cake material, and a mixture of waste filter cake material and oily sludge. The treated waste was formed into one-cubic yard blocks (treated waste monoliths or TWMs), which will be periodically examined for up to five years. Extensive sampling and physical and chemical analysis were performed on both the untreated and treated waste and on the reagent mix samples. Appendix C of this report describes in greater detail the demonstration site, the chemical and physical properties of the untreated and treated wastes, and the technology's performance during the demonstration. Appendix D briefly discusses several projects in which the Soliditech process was applied.

Results

The results of physical tests, chemical tests, and the economic analysis are summarized below.

Physical Tests

Extensive testing was conducted to determine (1) the physical characteristics of the untreated and treated wastes, (2) the short-term durability of the treated waste, and (3) the long-term morphology of the treated waste.

First, physical testing was performed to characterize the untreated and treated wastes. Bulk density of all wastes increased an average of 30 percent due to the addition of cement and additives, while water content and loss on ignition decreased. The average volume increase due to treatment was 22 percent. The permeability of the treated wastes was very low, with most values less than 1×10^{-7} cm/sec. These low permeability values compare favorably with the specifications in RCRA regulations for landfill liners (40 CFR Part 264, Subpart N). The unconfined compressive strength (UCS) values for the treated waste ranged from 390 to 860 psi. These values are well above the U.S. EPA guideline of 50 psi for solidification/stabilization and concrete-based waste treatment systems (U.S. EPA, 1986a).

The short-term durability of treated waste was also evaluated by conducting wet-dry and freeze-thaw tests. Wet/dry and freeze/thaw durability tests showed up to one percent weight loss after 12 cycles. While subsequent UCS tests showed approximately 70 percent loss of compressive strength, the values were still above the U.S. EPA guideline. It should be noted that while these tests measure only short-term durability, they represent more severe conditions than would normally be encountered by treated waste materials.

Long-term morphological examination of the solidified, treated waste monoliths (TWMs) is being conducted to characterize the homogeneity of mixing, extent of curing of the concrete-like matrix, and other potential long-term effects. After the 28-day curing period, an examination showed the oil and grease widely dispersed in globules throughout both the cast cylinders prepared for laboratory study and the TWMs. The millimeter-sized globules appeared to be isolated and not contained within a continuous pore system. Examination of the TWMs from the first batch of waste processed during the Soliditech demonstration showed a few large masses of oil and grease, suggesting that this batch of waste may not have been as thoroughly mixed as the latter batches. A few stress-relief cracks were noted along corners of some of the TWMs. After six months, several of the blocks contained distinct fractures that appeared to penetrate at least 10 cm in depth. No distinct color changes were evident on any of the blocks. Several of the

blocks contained light salt deposits on the surface. After one year, no additional fractures were observed; however, on a few of the TWMs the cracks appeared slightly wider.

Chemical Tests

Chemical analyses were performed on untreated and treated waste materials; on aqueous extracts generated by TCLP, EP Toxicity, and Batch Extraction Test (BET) procedures; and on leachates generated by non-destructive ANS 16.1 and Waste Interface Leaching Test (WILT) procedures.

Total chemical analyses of untreated and treated wastes showed the effects of the treatment process. The reagent mixture (Soliditech reagent, additives, cement, and water plus clean sand) contained 59 mg/Kg of arsenic, but analysis of the sand used in the formulation of the reagent mixture only contained 0.11 mg/Kg of arsenic. Chromium, copper, lead, nickel, and zinc were not detected in the sand, but were detected at low concentrations in the reagent mixture. The presence of these metals was attributed to the Soliditech reagent, additives, or cement. Concentrations of several phenols were found at the low mg/Kg level in the treated wastes. The origin of these semivolatile organic compounds (SVOCs) is unknown, although laboratory contamination and contribution by the Soliditech additives have been ruled out. Volatile organic compounds (VOCs) were detected at concentrations of up to 10 mg/Kg in the Off-Site Area One soil and the filter cake/oily sludge mixture. VOCs were not detected in the analyses of the treated wastes or in the environment above the mixer as the wastes were being processed. It is assumed that these VOCs were lost during waste collection and treatment.

Data from the five extraction and leaching tests show the Soliditech process to be generally effective at immobilizing heavy metals. These data are described below.

TCLP

Arsenic was detected in the TCLP extract of treated Off-Site Area One waste at a concentration of 0.017 mg/L, and lead was detected in the extract of the treated filter cake/oily sludge waste at 0.014 mg/L; these were the highest concentrations of metals of concern detected in extracts of the treated wastes. These concentrations represent reductions of 85 percent and greater than 99 percent, respectively, over the concentrations of these metals in the TCLP extract of the untreated wastes. Chromium was detected at a concentration of 0.063 mg/L in the extracts of both the treated filter cake waste and the reagent mixture. PCBs were not detected in the TCLP extracts of either the untreated or treated wastes.

EP Toxicity

Analyses of EP extracts showed no detectable PCBs in either the untreated or treated wastes. Arsenic and lead concentrations in the EP extract were reduced 55 to 99 percent by treatment.

BET

The BET extracts were obtained from three ratios of waste

to distilled water. Data from this test provide an indication of the maximum solute concentration and the capacity of the sample to provide a source of extractable solutes. No PCBs were detected in any BET extracts of the untreated or treated wastes. Aluminum, barium, calcium, and sodium were contributed by the Portland cement in the mixture. These were the major metal analytes found in the BET extracts. Lead concentrations were below the 0.050 mg/L detection limit in all but one (0.090 mg/L) sample extract of the treated waste compared to as much as 1.7 mg/L of lead in the extracts of the untreated wastes. Arsenic was present in both the untreated and treated waste extracts, but was reduced by up to 91 percent after treatment.

ANS 16.1

ANS 16.1 test results (performed on treated waste only) showed no detectable levels of PCBs, chromium, copper, lead, nickel, or zinc in the leachates generated from any of the three treated wastes. Arsenic was present at 0.005 to 0.008 mg/L in the leachate from the Off-Site Area One treated waste. This was the only analyte of potential concern and its concentration was quite low. Oil and grease concentrations of 1 to 3 mg/L were detected in the leachates from this same waste, although no oil and grease was detected in the solidified wastes from the other two areas. Due to the absence of contaminants of concern in the leachate, a "Leachability Index," as prescribed in the ANS 16.1 procedure, could not be calculated.

WILT

The WILT includes submerging 3-inch and 6-inch diameter by 18-inch long monolithic cylinders of treated waste in distilled water, then draining and analyzing the leachates at two-week intervals over a six-month time period. Data available after the first sixteen intervals showed no **detectable** PCBs. Arsenic decreased over the first nine intervals, by factors ranging from approximately 3 to 30 to values as low as 0.004 mg/L. Lead concentrations were generally below the detection limit of 0.05 mg/L. Total dissolved solids decreased by a factor of three from the first to the eighth interval. Calcium, a good indicator solutederived from the Portland cement, decreased by a factor of as much as five over these eight intervals.

Economics

An economic analysis of the Soliditech technology was conducted. The cost to treat 5,000 cubic yards of contaminated soil using a 10-cubic yard capacity mixer was calculated to be approximately \$152 per cubic yard. Labor and supplies were observed to be the major costs, accounting for approximately 33 and 41 percent, respectively, of the total cost. Section 4 of this report details the assumptions used to arrive at this estimate.

Field Reliability

No major operational problems were encountered with the Soliditech equipment during the demonstration. Mobilization and demobilization of the equipment was straightforward. The waste treatment phase of the demonstration was considered to be a success. Overall, the Soliditech equipment was observed to be reliable and easy to operate.

Conclusions

After reviewing the analytical data and observations from the Soliditech SITE demonstration, the following conclusions were made about the technology's effectiveness and cost, as well as the physical properties of the treated waste.

The Soliditech process can solidify contaminated soils, filter cake, and filter cake/oily sludges mixtures that are high in oil and grease content. Waste materials containing up to 17 percent oil and grease and 58 percent water were successfully solidified during the demonstration.

The process can immobilize heavy metals. Extract/leachate concentrations of cadmium, lead, and zinc were reduced by up to 99 percent.

The process can immobilize arsenic. Extract/leachate concentrations of arsenic were reduced by up to 85 percent.

Although low concentrations of several volatile organic compounds (VOCs) were detected in the untreated waste, no VOCs were detected in the treated waste samples or TCLP extract from the treated waste. The VOCs may have been lost during waste handling.

Several semivolatile organic compounds (SVOCs) were detected in the treated wastes and the TCLP extracts of the treated waste. Lower concentrations of these SVOCs were detected in the untreated wastes and untreated waste extracts/leachates, but none were detected in Soliditech's proprietary reagents and additives. The reason for the higher concentrations in the treated wastes and treated waste extracts/leachates is not known.

After a 28-day curing period, the treated wastes exhibited high physical stability; however, the

stability may be reduced over the long-term. Unconfined compressive strength (UCS) of the treated wastes was high; permeability was very low. The weight loss after 12 wet/dry and 12 freeze/thaw cycles was negligible (**one** percent or less). Visual inspection of the solidified/stabilized waste as well as the results of UCS testing after the 12 wet/dry and freeze/thaw cycles indicated long-term reductions in physical stability. Based on TCLP results, this reduced physical stability does not affect waste immobilization.

Treatment of the wastes resulted in volume increases of up to 59 percent (22percent average). Bulk density increased from 25 to 41 percent (31 percent average). A quantity of cement, reagent, additives, and water approximately equal to the weight of the waste was added during treatment.

Immobilization of VOCs, SVOCs, pesticides, and polychlorinated biphenyls (PCBs) could not be evaluated due to the low concentrations of these analytes in the wastes. Wastes containing suchorganics shouldbesubjected to a preliminary treatability study.

The Soliditech process was observed to be mechanically reliable. No equipment-related problems occurred during the demonstration.

The Soliditech process equipment is capable of mixing all components including the waste material, into a homogeneous, solidified product.

The Soliditech process is expected to cost approximately \$152 per cubic yard when used to treat large amounts (5,000 cubic yards) of waste similar to that found at the Soliditech demonstration site.

Section 2

Introduction

This section of the Applications Analysis Report describes the Superfund Innovative Technology Evaluation (SITE) program, discusses the purpose of this Applications Analysis Report, and describes the Soliditech technology. A list of key personnel who may be contacted for additional information is provided in Appendix A.

Purpose, History, and Goals of the SITE Program

The Super-fund Amendments and Reauthorization Act of 1986 (SARA) directed the U.S. Environmental Protection Agency (U.S. EPA) to establish an "Alternative or Innovative Treatment Technology Research and Demonstration Program." In response, U.S. EPA's Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) established a formal program called the Super-fund **Innovative Technology Evaluation (SITE)** Program, to accelerate the development and use of innovative cleanup technologies at hazardous waste sites across the country.

The SITE Program is comprised of the following five component programs:

- Demonstration Program
- Emerging Technologies Program
- Measurement and Monitoring Technologies Development Program
- Innovative Technologies Program
- Technology Transfer Program

This document was produced as a part of the SITE Demonstration Program. The objective of the SITE Demonstration Program is to develop reliable engineering performance and cost data on innovative alternate technologies, so that potential users can evaluate each technology's applicability to a specific site, compared to other alternatives. Demonstrations are conducted at hazardous waste sites (usually Superfund sites) or under conditions that closely simulate actual wastes and conditions, to assure the accuracy and reliability of information collected.

Data collected during a demonstration are used to assess the performance of the technology, the potential need for pre- and post-treatment processing of the waste, applicable types of waste and media, potential operating problems, and approximate capital and operating costs. Demonstration data can also provide insight into long-term operating and maintenance costs and long-term risks.

Technologies are selected for the SITE' Demonstration Program through annual requests for proposal (RFPs). Proposals are reviewed by OSWER and ORD staff to determine the technologies with the most promise for use at hazardous waste sites. Technologies are selected following interviews with the developers. To be eligible, technologies must be at the pilot or full-scale stage, must be innovative, and must offer some advantage over existing technologies. Mobile technologies are of particular interest. Cooperative agreements between U.S. EPA and the developer set forth responsibilities for conducting the demonstration and evaluating the technology. The developer is responsible for demonstrating the technology at the selected site, and is expected to pay the costs to transport, operate, and remove the equipment. U.S. EPA is responsible for project planning, sampling and analysis, quality assurance and quality control, preparing reports, and disseminating information.

The Technology Evaluation Report

The results of the Soliditech SITE project are incorporated in two basic documents -- the Technology Evaluation Report and the Applications Analysis Report. The Technology Evaluation Report (U.S. EPA, 1990) provides a comprehensive description of the demonstration and its results. It is intended for engineers making a detailed evaluation of the technology for a specific site and waste situation. These technical evaluators seek to understand in detail the performance of the technology during the demonstration and the advantages and risks of the technology for the given application. This information will be used to produce conceptual designs in sufficient detail to make preliminary cost estimates for the demonstrated technology.

Purpose of the Applications Analysis Report

The Applications Analysis Report is intended for decision makers responsible for implementing specific remedial actions. **The** report helps them to determine whether this technology has merit as an option in cleaning up their specific site. If the candidate technology appears to meet their needs, a more thorough analysis will be made based on the Technology Evaluation Report and on information from remedial investigations for the specific site.

Each SITE demonstration evaluates the performance of a technology in treating the particular waste found at the demonstration site. To obtain data with broad applications, attempts are made to select wastes frequently found at other Superfund sites.

In many cases, however, the waste at other sites will differ in some way from the waste tested. The successful demonstration of a technology at one site does not assure that it will work equally well at other sites. Data obtained from the demonstration may have to be extrapolated to estimate the total operating range of the technology. The extrapolation can be based on both demonstration data and other information available on the technology. Additionally, information contained in Appendix D was considered while preparing this report.

To encourage the general use of demonstrated technologies, U.S. EPA evaluates the applicability of each technology to sites and wastes other than those tested, and studies the likely costs of these applications. The results are presented in the Applications Analysis Report.

Soliditech Process Description

The Soliditech process blends waste material with pozzolanic material (such as fly ash), kiln dust, or cement; water; proprietary additives; and Urrichem, a proprietary reagent. The process equipment, including a mixer, is readily transportable on one or two trailers. The equipment is self-contained and requires minimal set-up time. Two personnel are required to operate the equipment. Other Soliditech personnel **are** required for support activities such as quality control, chemical formulation, and office support. Personnel are also required to load the waste material and **remove the** treated waste.

The Soliditech waste treatment process consists of the pre-treatment processing of the waste material, the actual treatment of the waste, and the handling and disposal of the treated waste and residuals. The Soliditech equipment is shown in Figure 1 of this report.

Principal Treatment Operations

Soliditech, Inc. uses a batch process to treat waste material. A schematic diagram of this process is shown in Figure 2. The operating capacity is governed by the size of the mixer, the amount of time required to load and discharge the mixer, and the amount of mixing time required for the waste material and the reagents and additives. The two mixers used during the SITE demonstration had nominal capacities of 2 and 10 cubic yards. The maximum capacity of the 10-cubic yard mixer was 13 cubic yards.

The following materials are mixed during the processing:

- Waste Material
- Water
- Urrichem
- Additives
- Cement

Materials are added while the mixer is operating to ensure a thorough mixing. Once all the materials are added to the mixer, they are thoroughly blended. The mixer works both by circular rotation of the blades and end-to-end tilting. The mixing process continues until the operator or chemist deter-

mines that the materials are thoroughly homogenized, anywhere from 15 to 60 minutes per batch.

Immediately after treatment, the treated waste material must be discharged to prevent hardening inside the mixer. The material may be placed on the ground, in a basin, in forms, or in roll-off boxes for transport.

After treatment and discharge, any residual materials left in the mixer can be blended with the next batch of waste to be treated. Alternately, the mixer can be decontaminated with a high-pressure steam cleaner. If the residual material is left in the mixer for too long, it will harden and may impede further use of the mixer. Wastewater and solid residual material from decontamination can be used in treating the next batch of waste or can be collected and stored for treatment or disposal.

Pre-Treatment Processing

The pre-treatment requirements of this process are minimal. Waste materials to be treated should contain no solids larger than approximately one foot in diameter. If not readily broken up during mixing, particles larger than this can restrict the rotation of the mixer blades and can clog the discharge port of the mixer. Due to sampling constraints during the SITE demonstration, all solid wastes were screened through a steel screen with 4-inch by 4-inch square openings to remove large objects.

Waste materials containing more than 30 percent oil or water require pre-treatment to reduce the amount of free liquid. For the SITE demonstration, the pre-treatment consisted of blending the waste oily sludge with contaminated filter cake to increase the solids content. This method allows both the oily sludge and the contaminated filter cake to be treated together and conserves both time and additives. Clean or contaminated solids or other additives can be used for this pre-treatment.

Waste materials with low moisture contents are not considered to require special pre-treatment, since water is normally added to the process.

If the waste material has a pH of greater than 12 or less than 2, it must be neutralized before treatment. Ambient temperatures above freezing are normally required during the treatment process and the first 24 to 48 hours of the curing period.

Residuals Handling

Residuals from the Soliditech process include treated waste material; washwater and residuals from cleaning and decontaminating the mixer; any spilled treated or untreated waste material; any treated or untreated waste material used for on-site testing; any protective clothing, covering, or liner material; and any personnel decontamination water.

The solidified waste material can be transferred directly to its ultimate on- or off-site storage location or it can be placed in drums, forms, or other containers for temporary storage. Residual solids and liquids from treatment and decontamination can be treated immediately with the next batch of waste, drummed for later treatment, or drummed for off-site treatment.

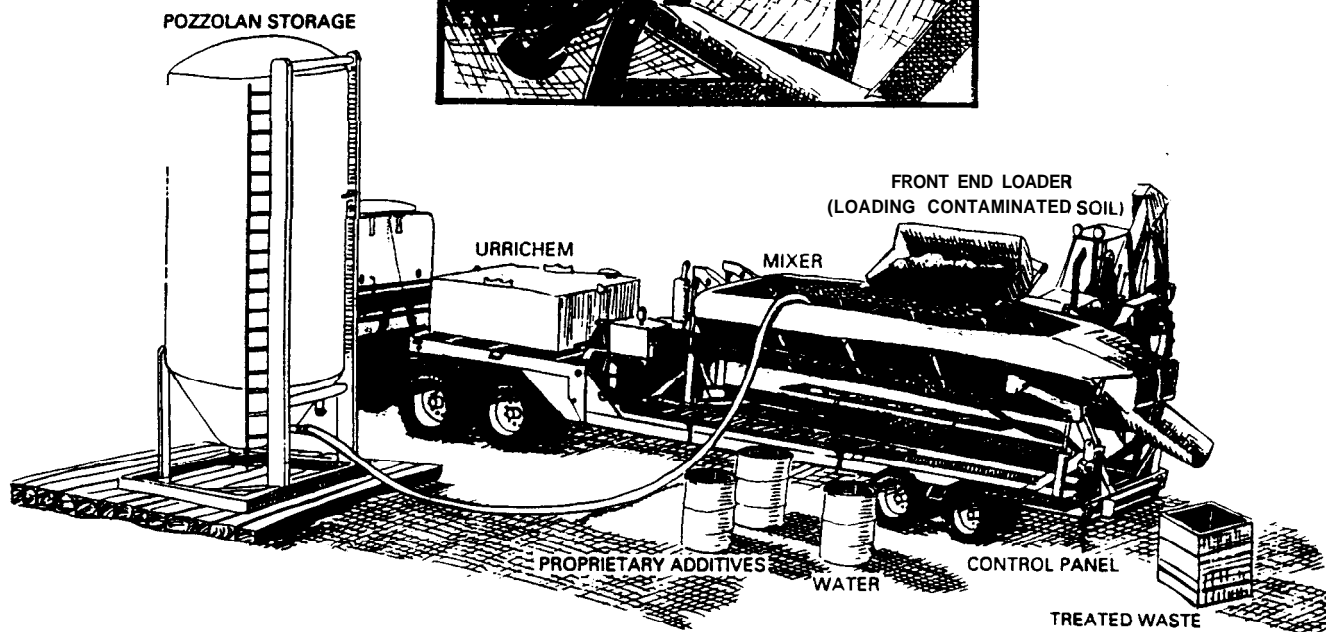


Figure 1. Soliditech Processing Equipment

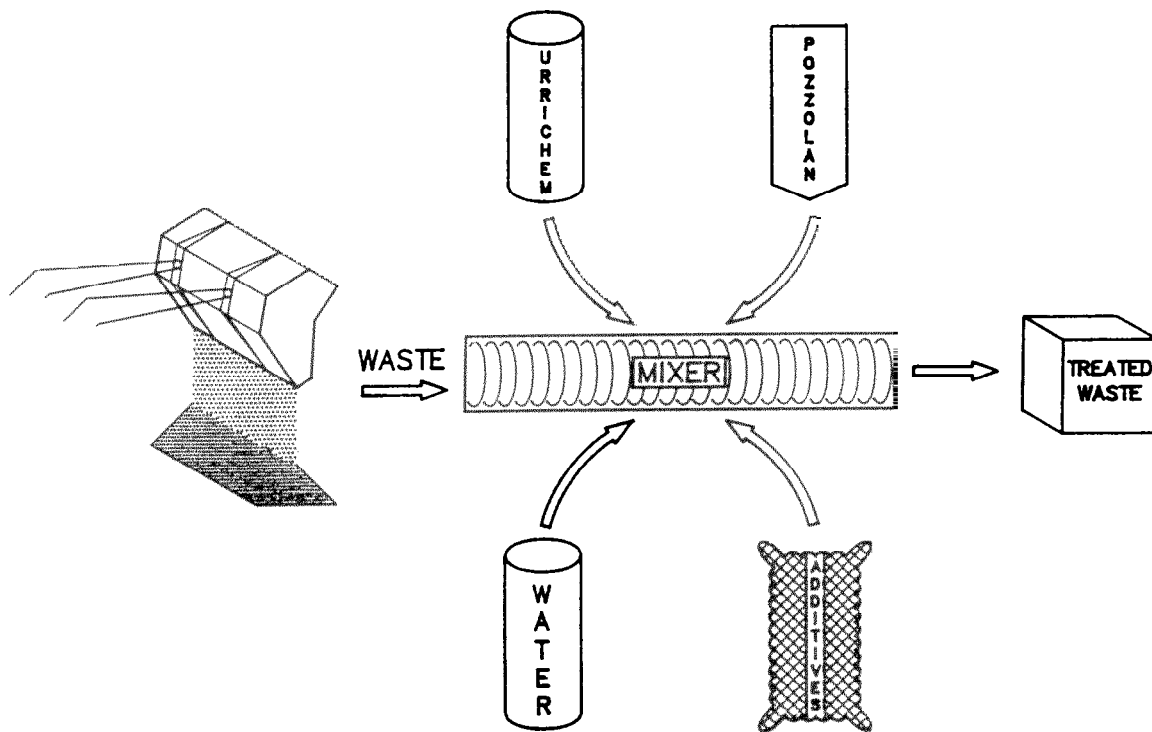


Figure 2. Soliditech Process Schematic

or disposal. Contaminated clothing and other materials can be drummed for off-site disposal.

If the solidified waste material contains a listed hazardous waste, it must continue to be treated as hazardous waste. Once solidified, however, the waste material can be disposed of in a permitted land-based hazardous waste storage facility. If this process is used for theremediation of a CERCLA site, U.S. EPA may consider allowing the treated waste to remain on-site with appropriate safeguards, such as a double-liner containment system with a leachate detection system and cap.

Soliditech Technology

The Soliditech process is similar to **other** cement-based solidification processes, except that it uses a unique reagent (Urrichem) to aid in stabilizing the waste material. The process uses a batch type mixer which allows precise control of the extent of mixing of the waste material with the reagent and additives. This process also allows the use of a pozzolanic material (such as fly ash) or kiln dust in place of Portland cement.

Section 3

Technology Applications Analysis

This section of the report assesses the general applicability of the Soliditech technology to contaminated waste sites. The analysis is based primarily on the SITE demonstration results since limited information was available on **other** applications of the technology.

Technology Evaluation

The demonstration of the Soliditech, Inc. solidification/stabilization process was designed to evaluate four primary objectives:

Determine how well the Soliditech technology solidifies and stabilizes waste materials found at the Imperial Oil Company/Champion Chemical Company Superfund site in Morganville, New Jersey.

Determine how well the solidified material retains its structure and stability over time.

Determine the volume and mass increase or decrease of the solidified material after adding treatment ingredients.

Develop reliable capital and operating costs for the technology for use in the Superfund decision-making process.

A SITE Demonstration Plan was prepared (PRC, 1988) and the Soliditech technology was demonstrated in December 1988. Analytical tests were performed on samples of both the untreated and treated waste materials collected during the demonstration. These results are discussed in the Technology Evaluation Report (U.S. EPA, 1990) and are summarized below.

Effectiveness of Solidification/Stabilization Process

Three distinct waste types were treated during the Soliditech demonstration -- soil, used filter cake, and filter cake/oily sludge mixture. These three wastes were sampled for chemical and leaching/extraction testing prior to treatment and again after a 28-day curing period following treatment. Additionally, the reagent, additives, cement, and water used by Soliditech were mixed and sampled to check for possible chemical analyte contributions. The effectiveness of the Soliditech process in reducing the environmental impact of contamination was assessed through various leaching or extraction tests performed on samples generated during the demonstration. These tests included the TCLP, EP Toxicity, ANS 16.1, BET, and WILT

tests, which are described in the Soliditech demonstration plan (PRC, 1988).

The data indicate that the Soliditech process is effective in immobilizing heavy metals. Arsenic, lead, and zinc concentrations in the treated waste extracts were generally reduced **below** detection limits. Actual reductions in treated versus untreated leachate concentrations for these metals can only be estimated. A lead reduction of 99 percent was found in EP leachates from the filter cake waste. Lead and zinc reductions of greater than 98 percent were observed in the other TCLP, EP, and BET extracts. One BET extract of treated Off-Site Area One waste contained 0.090 mg/L of lead. This was the highest lead concentration found in any treated waste extract/leachate. All other TCLP, EP, BET, and ANS 16.1 extracts/leachates contained less than 0.050 mg/L (the detection limit) of lead. One ANS 16.1 leachate of treated filter cake/oily sludge contained 0.037 mg/L of zinc. This was the highest zinc concentration found in any treated waste extract/leachate. All other TCLP, EP, and BET extracts contained less than 0.020 mg/L (the detection limit) of zinc. Arsenic reductions up to 91 percent were observed in the extracts/leachates.

While Aroclors 1242 and 1260 (PCBs) were detected in the untreated and treated wastes, no Aroclors were detected in the extracts/leachates of any of the untreated or treated waste samples.

Low levels of several VOCs were detected in the untreated waste samples and the TCLP leachates of these samples. None of these compounds were detected in the TCLP extracts of the treated waste samples.

Low levels of SVOCs were detected in the untreated waste samples. Only one of these compounds was detected in the TCLP extracts of an untreated waste sample. No SVOCs were detected in the TCLP extracts of the treated waste samples.

Total dissolved solids (TDS) and oil and grease extract/leachate concentrations were generally higher from the treated waste than from the untreated waste. Total organic carbon (TOC) analyses were performed on the BET extracts. In seven of nine cases, the TOC concentrations in the BET extract were greater in the treated waste samples.

The Soliditech process also appears to increase the concentrations of several analytes in the extracts/leachates collected from the treated samples. Aluminum, barium, calcium, chromium, copper, lead, nickel, and sodium were detected in the

reagent mix. According to Soliditech, these metals originate from the Portland cement. The presence of selenium in the reagent mix EP extract has not been accounted for.

Phenol, 2,4-dimethylphenol o-cresol, and p-cresol were found in the TCLP extracts of all of the treated waste samples at higher concentrations than in the untreated waste samples. These compounds were only analyzed for in the TCLP extracts. Benzyl alcohol was also found in the TCLP extract of the treated Off-Site Area One waste. None of these compounds were detected in the TCLP extract collected from the Soliditech reagent mix. The source of these phenolic compounds is unknown.

Structural Stability of Treated Waste Material

The solidified waste was tested for unconfined compressive strength (UCS), wet/dry durability, freeze/thaw durability, bulk density, water content, loss on ignition, and permeability. The morphology of the solidified materials was also examined both in the field and in the laboratory, using various techniques. These tests are summarized below.

The bulk density of the waste increased by an average of 3.1 percent due to the addition of cement and additives during treatment process. The permeabilities of the treated wastes were very low, with values of ranging from 8.9×10^{-9} to 4.5×10^{-7} cm/sec. UCS values ranged from 390 to 860 psi. These properties were directly related to the amount of cement used in the treatment process. The water content of the treated waste ranged from 13 to 21 percent, while loss on ignition (a measure of total water and organic content) ranged from 34 to 41 percent. Wet/dry and freeze/thaw durability results were good, with one percent or less weight loss over each cycle of the 12-cycle test run.

The solidified wastes were examined for homogeneity of mixing, the extent of curing of the concrete-like matrix, the mineralogic composition of the solidified mass, the presence of voids within the solidified matrix, and other potential long-term effects. Examining the morphology of the treated waste monoliths (TWMs) will provide long-term data on how well these large blocks will withstand environmental exposure. Preliminary observations showed oil and grease widely dispersed in globules throughout both the cast cylinders prepared for laboratory study and the one-cubic yard TWMs. The millimeter-size globules appeared to be isolated and not contained within a continuous pore system. A detailed characterization will be published when the long-term study is completed.

The TWMs from the first test run showed a few large masses of oil and grease. This first batch of waste processed during the demonstration may not have been thoroughly mixed. A few stress relief cracks were noted along the corners of some of the TWMs. After six months, several of the large blocks contained distinct fractures that appeared to penetrate at least 10 cm into the TWMs. These cracks are not unexpected, since a mixture very rich in cement was used to solidify the waste, the treated waste set very rapidly, and no reinforcement or aggregate

was used in the solidified waste. No distinct color changes were evident on any of the blocks. Several of the blocks contained light salt deposits on their surfaces, suggesting either weeping from the blocks or surface flow of condensation that may have developed under the cover protecting the TWMs. After 1 year, no additional fractures were observed; however, on a few of the TWMs the cracks appeared slightly wider.

Volume and Mass Increase Due to Solidification/Stabilization Process

The weight or volume and the bulk density of all Soliditech ingredients and waste materials were measured or calculated to assess the volume and mass increase of the waste due to the Soliditech treatment process. The bulk densities of the wastes increased from 25 to 4.1 percent, with an average increase of 30 percent due to addition of cement and additives during treatment. The volume change of the three wastes ranged from no change to a 59 percent volume increase. The average volume change was a 22 percent increase.

Capital and Operating Costs

The cost to treat a site containing 5,000 cubic yards of contaminated waste using the Soliditech process is estimated to be approximately \$152 per cubic yard. This figure is based on both actual and estimated cost information supplied by Soliditech, actual costs incurred by U.S. EPA during the demonstration, and estimates of costs to perform a large-scale treatment and cleanup of a Superfund site containing similar waste materials. Section 4 of this report details the assumptions used to make this estimate.

Site Factors

Site-specific factors have an impact on the application of the Soliditech technology. These factors should be considered before using this technology.

Space

The Soliditech process can be applied to small or large amounts of solids or sludge. Soliditech uses a mixer mounted on a trailer that can readily be transported and moved around the site. A 30- by 100-foot area is required for the mixer and associated equipment. This area should be relatively level. It can be paved or covered with compacted soil or gravel. Another small area is required for material storage. The size of this area depends upon the amount of waste to be treated.

The cement or pozzolanic materials storage hopper requires a firm foundation. This could be a concrete pad, a 15-foot square base of 12-inch square lumber (as used for the demonstration), or some other type of firm base capable of supporting up to 25,000 pounds. A 30- by 100-foot area is required for the hopper, an air compressor, and an access area.

An area approximately 10- by 10-feet is required for a portable scale and several other small pieces of equipment such as a viscometer, used for formulating and testing the mixtures. A trailer or indoor office space is useful for this equipment, especially in winter, but not necessary. Figure 1 depicts the

Soliditech processing equipment as operated during the SITE demonstration.

Additional space is required for a field office, a decontamination area, storage areas, and parking.

Emissions

The Soliditech process is primarily designed to treat solid and semi-solid (sludge) materials. Several sources of emissions are possible. Spills can readily be picked up and treated with the waste material. Volatile emissions from wastes containing such compounds are difficult to control. Excavation, transport, and treatment of waste containing volatile organic compounds will result in volatile emissions.

As a preventative measure, the Soliditech mixer can be enclosed under a cover. The air under the cover is maintained at a negative pressure by pumping it through a carbon filter. This reduces volatile emissions from the treatment phase of the process. Losses during excavation and transport would be no different from those for any other treatment process. Volatile losses from the treated waste material should be minimal -- especially when compared to the mixing process -- since the treated material is no longer being actively mixed, is relatively impervious, and is usually configured to have a low surface-to-volume ratio. Fugitive dust emissions during waste collection and transfer can also be minimized by covering the mixer.

Site Access

Site access requirements are minimal. The site must be accessible to tractor trailer trucks of standard size and weight. The roadbed must be able to support such a vehicle.

Water and Wastewater

The Soliditech process can treat dry waste as well as waste that contains moisture. The process requires water as one of the ingredients. Waste containing up to 25 percent water (by weight) can be accommodated. This water can be in the form of wet soil, sludge, contaminated ground water, or even contaminated washwater. Wastes containing more than 25 percent water require special formulation or pretreatment.

The process generates a small amount of wastewater from cleaning the equipment and from personnel decontamination. As previously mentioned, this water can be added to subsequent batches of waste.

The technology normally should involve no discharge to or disruption of surface water drainage.

C l i m a t e

Several climatic conditions can affect the Soliditech process. To obtain optimal physical properties of the treated waste, the temperature of the treated waste should remain above freezing, especially during the first 24 hours after treatment. Although adjustments can be made to treat wastes at freezing temperatures, this may result in incomplete setting of the solidified waste, with lower UCS, and poorer durability properties. At subzero temperatures, the water used in the additives

and the process will also freeze. The process should therefore be used only when overnight temperatures are predicted to be at least several degrees above freezing.

Heavy rain can slow or stop any operation that requires earthmoving equipment, such as the Soliditech process, by creating mud and slippery conditions. Excavation areas may also fill with water, and workers may find it difficult to work.

High wind conditions can scatter particles during waste collection and transport operations and also when adding waste and cement or pozzolanic material to the mixer. The latter can be controlled using covers, wind breaks, or alternate methods of transferring the materials to the mixer. The potential user of this technology should be aware of any possible high wind conditions.

Electricity

A source of 30-amp 120-volt electricity is required to power the blower used to transfer the cement or pozzolanic material from the storage hopper to the mixer. This same service is adequate to power the field-testing equipment and a portable steam cleaner used to clean the mixer. A portable generator can supply this electricity.

Services and Supplies

A number of services and supplies are required for the Soliditech technology. Most of these services and supplies can be obtained locally.

The Soliditech process uses large quantities of water and cement or pozzolanic materials. These materials can usually be obtained locally. Certain additives may also be obtained locally by Soliditech, Inc.

The Soliditech mixer is diesel-powered. Diesel fuel may be obtained locally. Gasoline or diesel fuel for a portable generator and earthmoving equipment may also be obtained locally.

Equipment such as cranes, forklifts, front-end loaders, backhoes, steam cleaners, an office trailer, portable toilets, and scales to weigh additives and waste can all be obtained locally from industrial rental companies. Supplies such as tools, drums, plastic sheeting, and lumber can be purchased locally.

A local security service may be necessary to protect the equipment at night and to prevent access to the site by unauthorized personnel.

Appropriate Waste and Site Conditions

Whether or not the solidification/stabilization process is appropriate for hazardous waste site remediation depends upon the nature of the waste, the chemical and physical properties desired or required for the treated waste, the overall treatment cost, and the physical conditions at the site. These factors must be assessed before selecting a site remediation method. The suitability of the waste for treatment including the properties of the waste is determined through treatability testing, while the

physical conditions at the site are assessed during a site visit, which includes the technology vendor. A thorough assessment should include the following steps (U.S. EPA, 1989):

- Review previous studies of similar wastes.
- Perform treatability testing on wastes from the site.
- Identify potential pretreatment options to improve the waste treatment process.
- Assess site conditions affecting the treatment of waste and the disposal of the treated waste.
- Review site and process health and safety requirements.
- Determine waste disposal requirements and overall costs.

Regulatory Requirements

This section discusses the Federal regulatory requirements for the Soliditech technology and analyzes these requirements in view of the demonstration results. State and local regulatory requirements, which may be more stringent, will also have to be addressed.

Comprehensive Environmental Response, Compensation and Liability Act

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) authorizes the Federal government to respond to releases or potential releases of any hazardous substance into the environment, as well as to releases of pollutants or contaminants that may present an imminent or significant danger to public health and welfare or the environment.

As part of the requirements of CERCLA, U.S. EPA has prepared the National Contingency Plan (NCP) for hazardous substance response. The NCP is codified in Title 40 Code of Federal Regulations (40 CFR) Part 300, and delineates the methods and criteria used to determine the appropriate extent of removal and cleanup for hazardous waste contamination.

The Superfund Amendments and Reauthorization Act of 1986 (SARA) amended CERCLA, and directed U.S. EPA to:

- use remedial alternatives that permanently and significantly reduce the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants;
- select remedial actions that protect human health and the environment, are cost-effective, and involve permanent solutions and alternative treatment or resource recovery technologies to the maximum extent possible; and
- avoid off-site transport and disposal of untreated hazardous substances or contaminated materials when practicable treatment technologies exist (Section 121(b)).

The NCP includes solidification as a possible cost-effective technology for remediation of contaminated soils and sediments (Section 300.70). The preference under SARA for permanent solutions that reduce waste volume, toxicity, or mobility applies to the use of solidification technologies at CERCLA sites.

CERCLA Response Actions

In general, two types of responses are possible under CERCLA -- removals and remedial actions. Solidification technologies are unlikely to be part of a CERCLA removal. Unless the removal is part of a remedial action, removals are limited in the amount of time and money that can be spent. Superfund-financed removals cannot exceed 12 months in duration or \$2 million in cost, in most cases.

Remedial actions are governed by SARA amendments to CERCLA. As stated above, these amendments promote remedies that permanently reduce the volume, toxicity, and mobility of hazardous substances, pollutants, or contaminants. However, U.S. EPA is required to review any remedial action in which hazardous substances, pollutants, or contaminants remain at the site. A remedial action in which hazardous substances are treated by solidification and disposed of at the site must be reviewed by U.S. EPA every five years to assure the continued protection of human health and the environment.

On-site remedial actions must comply with federal and more stringent state applicable or relevant and appropriate requirements (ARARs). ARARs are determined on a site-by-site basis. CERCLA provides only six waivers to meeting ARARs during a remedial action (Section 121(d)(4)). ARARs also dictate the degree of cleanup necessary at CERCLA sites. If solidification is chosen as the sole technology for a remedial action, then the solidification process must meet ARARs for cleanup at that site.

Contaminated soil and debris are the primary type of waste at most CERCLA sites. If the soil and debris contains hazardous wastes **that** are subject to RCRA Land Disposal Restrictions (LDR), it must be treated to comply with LDR treatment standards or obtain a variance from U.S. EPA. See the RCRA discussion below for further details.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA), an amendment to the Solid Waste Disposal Act (SWDA), was passed in 1976 to address the problem of how to safely dispose of the enormous volume of municipal and industrial solid waste generated annually. RCRA specifically addressed the identification and management of hazardous wastes. The Hazardous and Solid Waste Amendments of 1984 (HSWA) greatly expanded the scope and requirements of RCRA.

RCRA regulations concerning hazardous waste identification and management are located in 40 CFR Parts 124, 260-272. U.S. EPA and authorized States implement and enforce RCRA regulations.

The key to determining whether RCRA regulations apply to the Soliditech process is the presence of hazardous wastes. U.S. EPA defines hazardous waste in 40 CFR Part 261. If hazardous wastes are being treated by solidification, the owner/operators of treatment or disposal facilities must obtain a RCRA permit (40 CFR Part 270) from U.S. EPA or the authorized state. Owners or operators are also subject to RCRA permit or interim status standards defined in 40 CFR Parts 264 or 265, respectively, depending on the type of unit (tank, container, or landfill) used for the solidification process.

Generators of hazardous wastes (defined in 40 CFR Part 260) do not need RCRA permits if they conduct the solidification process in tanks or containers subject to generator accumulation requirements. Generators should note that State hazardous waste programs may be more stringent than those of U.S. EPA, and may require a separate permit for the solidification process.

Once hazardous wastes are treated by solidification, the treated waste or residue may still be a hazardous waste. Applicable RCRA requirements could include a Uniform Hazardous Waste Manifest if the treated waste is transported, restrictions on placing the treated wastes in land disposal units, time limits on accumulating treated waste, and permits for storing treated waste.

RCRA Land Disposal Restrictions

HSWA mandated that U.S. EPA develop land disposal restrictions (LDR) prohibiting the placement of untreated hazardous waste in land disposal units. U.S. EPA set treatment standards for restricted hazardous wastes based on the Best Demonstrated Available Technology (BDAT) determined for each waste. Once a restricted waste is treated to meet treatment standards, the waste may be land-disposed. By May 8, 1990, all RCRA hazardous wastes will have been evaluated and treatment standards established as appropriate.

U.S. EPA may grant national variances to the LDRs if it determines that the capacity to treat restricted wastes is presently unavailable. Other variances to the restrictions are issued on a case-by-case basis and may extend for up to two years. A restricted waste may be land-disposed without treatment under such variances; however, the land disposal unit receiving the waste must comply with minimum technological requirements specified in Section 3004(o) of RCRA. U.S. EPA may also grant treatability variances in cases where the restricted wastes were formed by inadvertent mixing or where the restricted wastes are different in physical form from those wastes used to set the treatment standards.

Currently, U.S. EPA has granted several national capacity variances from the LDRs for contaminated soil and debris resulting from CERCLA responses and RCRA corrective action measures. These variances will expire during 1990 and 1991. After 1991, all contaminated soil and debris must be treated to meet LDR standards.

RCRA Corrective Action

HSWA greatly expanded U.S. EPA's authority under RCRA to require corrective action. Section 3004(u) of HSWA requires corrective action for releases of hazardous wastes or constituents from any solid waste management unit at a storage, treatment, or disposal facility that is seeking or otherwise subject to a RCRA permit. Section 3004(u) also requires that these permits contain assurances of financial responsibility for complying with corrective action. Moreover, Section 3004(v) authorizes U.S. EPA to require corrective action beyond the facility boundary. Section 3008(h) of HSWA authorizes U.S. EPA to require corrective action or other necessary response measures whenever it is determined that there has been a release of hazardous wastes or constituents from a facility authorized to operate under Section 3005(e) of RCRA. Under RCRA regulations, the facility owner or operator is responsible for conducting the corrective action.

Toxic Substances Control Act

The disposal of PCBs is regulated under Section 6(e) of the Toxic Substances Control Act of 1976 (TSCA). PCB treatment and disposal regulations are described in 40 CFR Part 761. Materials containing PCBs in concentrations between 50 and 500 parts per million (ppm) may either be disposed of in TSCA-permitted landfills or destroyed by incineration at a TSCA-approved incinerator; at concentrations greater than 500 ppm, the material must be incinerated. Therefore, soil contaminated with up to 500 ppm of PCBs may be suitable for solidification. Where individual state standards are stricter than federal standards, solidification may be unacceptable as a pre-disposal remedy.

Clean Air Act

The Clean Air Act (CAA) requires that treatment, storage, and disposal operations comply with primary and secondary ambient air quality standards. During the excavation, transportation, and treatment of the waste material, fugitive emissions are possible. Steps must be taken to prevent or minimize the impact from fugitive emissions, such as covering the waste material with industrial strength (40-mil) plastic during transportation and storage prior to processing. State air quality standards may require additional measures to prevent fugitive emissions.

Occupational Safety and Health Act

Superfund remedial actions and RCRA corrective actions must be performed in accordance with the Occupational Safety and Health Act (OSHA) requirements detailed in 29 CFR Parts 1900 through 1926. State occupational safety and health requirements must also be met, and may be stricter than the federal standards.

Regulatory Requirements Applied to the Soliditech Technology Demonstration

No federal, state, or local permits were required for the Soliditech demonstration because any Superfund removal or

remedial action conducted entirely on-site is exempt from such permit requirements.

The hazardous waste materials at the Imperial Oil Company/Champion Chemical Company site were characterized prior to the demonstration to determine whether they were suitable for treatment with the Soliditech technology. Waste materials from many different areas in and around the site were analyzed for chemical and physical properties. These analyses were performed in accordance with RCRA Section 261.24 (Characteristic of EP Toxicity).

Although no residual hazardous wastes were generated from the Soliditech treatment process, contaminated clothing and decontamination water from the demonstration constituted hazardous waste. The New Jersey Department of Environmental Protection (NJ DEP) agreed to dispose of these wastes. RCRA regulations will be followed for transporting contaminated clothing, decontamination water, and the solidified waste material to a disposal facility. Any New Jersey requirements for the transport of hazardous waste will also be met.

Although the TWMs are being stored on-site for longer than 90 days, no storage permit was required because any remedial or removal action conducted entirely on-site at a Superfund site is exempt from the permit process as delineated by Section 121 of CERCLA as amended by SARA. However, all the substantive RCRA requirements for miscellaneous units were met. The TWMs were entirely enclosed in plastic to protect them from precipitation and prevent any run-on and run-off. In addition, the TWMs are examined in detail semi-annually.

Ordinarily, the treated waste material would have to comply with LDR treatment standards. However, in the case of the Soliditech demonstration, the waste material was exempt by a national capacity variance for contaminated soil and debris.

Under TSCA, PCB-contaminated wastes may be disposed of in either a permitted landfill or destroyed by incineration if concentrations do not exceed 500 ppm. Concentrations of PCBs detected in the waste material at the Imperial Oil Company/Champion Chemical Company site did not exceed 500 ppm, and therefore can be disposed of in a permitted disposal facility.

Approximately nine cubic yards of contaminated soil were excavated from the waste pile and from an off-site area for the Soliditech demonstration. To prevent or minimize the potential impact from fugitive emissions, the waste material was covered with plastic during transportation and storage prior to treatment. The steps taken to minimize fugitive emissions were consistent with State of New Jersey primary and secondary ambient air quality requirements.

To meet OSHA requirements, all personnel were required to wear appropriate personnel protective equipment, including respirators, coveralls, boots, and gloves, during all on-site work involving heavy equipment and hazardous waste.

Table 1 summarizes federal and state ARARs for the Soliditech technology, the basis or applicability of the requirements, and the recommended response to the requirements.

Technology Performance During the Demonstration

No major operational problems were encountered during the Soliditech demonstration. Several minor problems did occur and are discussed below.

Mobilization and Demobilization

Approximately one day each was required to mobilize and demobilize Soliditech storage containers and treatment equipment. This mobilization and demobilization time is necessary regardless of the size of the job, and does not include time for site preparation and restoration. At an actual remediation on a hazardous waste site, the time expended in mobilization and demobilization would be insignificant compared to the actual waste treatment activities.

The large Soliditech mixer, although cleaned prior to the SITE demonstration, contained some residual material that could have contributed chemical contamination to the test runs. Soliditech personnel scraped as much of this material out of the mixer as possible and then steam-cleaned the mixer prior to its use. A sample of the material scraped from the mixer was collected, chemically analyzed, and determined not to have contributed to the contamination found in the treated waste.

Because of the lack of traction in the equipment mobilization area, Soliditech personnel were not able to erect the pozzolan storage hopper in the normal manner. A large tow truck with an extendable boom was required to help lift this storage hopper into position.

The electrical blower used to transfer cement out of the pozzolan storage hopper required more amperage than could be supplied by either a small portable generator or an outdoor electrical outlet near the location of the demonstration. This problem was solved by replacing a defective electrical circuit breaker controlling the outdoor electrical outlet.

Treatment

The waste treatment phase of the demonstration was considered to be a success. No mechanical problems occurred with the Soliditech equipment during the demonstration. The Soliditech technology was observed to be very simple and reliable. There were no health and safety-related problems. All personnel present at the demonstration read and followed the site-specific health and safety plan and observed OSHA health and safety regulations.

There was a delay in the delivery of earthmoving equipment and thus in the collection of the waste material. This problem was not attributable to Soliditech but did cause a slight delay in treatment operations.

Table 1. Federal and State ARARS for the Soliditech Technology

<u>Process Activity</u>	<u>ARAR</u>	<u>Description</u>	<u>Basis</u>	<u>Response</u>
Waste characterization (untreated waste)	RCRA 40 CFR Part 261 or state equivalent	Identifying and characterizing the waste as treated	A requirement of RCRA prior to managing and handling the waste	Chemical and physical analyses must be performed
Excavation	Clean Air Act 40 CFR 50.6 and 40 CFR 52 or state equivalent	Management of fugitive air emissions	Fugitive air emissions may occur during excavation and material handling and transport	Excavations should be conducted using equipment that will minimize the development of fugitive air emissions; cover waste material with plastic during transportation.
Storage prior to processing	RCRA 40 CFR Part 264 or state equivalent	Standards applicable to the storage of hazardous waste	Excavation may generate a hazardous waste that must be stored in a waste pile, container, etc.	If in a waste pile, the material should be placed on and covered with plastic and tied down to minimize fugitive air emissions and volatilization.
Waste processing	RCRA 40 CFR Parts 264 and 265 or state equivalent	Standards applicable to the treatment of hazardous waste at permitted and interim status facilities	Treatment of hazardous waste must be conducted in a manner that meets the operating and monitoring requirements	Previous testing indicates that waste to be treated is compatible with the Soliditech technology. Equipment must be operated and maintained daily. Air emissions must be characterized by continuous emissions monitoring.

(continued)

Table 1. (continued)

<u>Process Activity</u>	<u>ARAR</u>	<u>Description</u>	<u>Basis</u>	<u>Response</u>
Storage after processing (if applicable)	RCRA 40 CFR Part 264 or state equivalent	Standards that apply to the storage of hazardous waste	The treated material may be be cured and stored prior to final land disposal	The treated material stored in a manner that prevents the deterioration, such as erosion, runoff, runoff, etc.
Waste characterization (Treated waste)	RCRA 40 CFR Part 261 or state equivalent	Standards that apply to waste characteristics	A requirement of RCRA prior to managing and handling the waste	Chemical, physical, and extraction tests must be performed. The tests will be in accordance with those specified in this section.
On-site/off-site disposal	RCRA Subtitle D (State Regulation) or state equivalent	Standards that apply to the disposal of solid waste	The treated waste may no longer be a hazardous waste but only a solid waste	The state regulatory agency must be contacted to obtain appropriate design criteria for a solid waste landfill.
	RCRA 40 CFR Part 268 or state equivalent	Standards that restrict the placement of certain wastes in or on the ground	The nature of the waste may be subject to the LDRs	The waste must be characterized to determine if the LDRs apply; treated wastes must be tested and results compared.

(continued)

Table 1. (continued)

<u>Process Activity</u>	<u>ARAR</u>	<u>Description</u>	<u>Basis</u>	<u>Response</u>
On-site/off-site disposal (continued)	RCRA 40 CFR Part 264 or state equivalent	Standards that apply to landfilling hazardous waste	The treated waste may still be a hazardous waste and subject to LDRs	Treated wastes must meet applicable standards or a variance must be sought from the U.S. EPA Administrator. The land disposal unit must meet minimum technology requirements.
	TSCA 40 CFR Part 761 or state equivalent	Standards that restrict the placement of PCBs in or on the ground	Waste containing less than 500 ppm of PCBs may be land disposed or incinerated	The treated material will be analyzed for PCB concentration. Approved PCB landfills or incinerators must be used for disposal.
	RCRA 40 CFR Part 262 or state equivalent	Manifest requirements and packaging and labeling requirements prior to transporting	The material must be manifested and managed as a hazardous waste	U.S. EPA must issue an I.D. number.
Transportation for off-site disposal	RCRA 40 CFR Part 263 or state equivalent	Transportation standards	The material must be transported as a hazardous waste	A transporter licensed by the U.S. EPA must be used to transport the hazardous waste according to U.S. EPA regulations.

Overall Demonstration Schedule

The overall demonstration schedule allowed one day to mobilize the Soliditech equipment, three days for waste treatment, and one day for demobilization. Because of delays in the collection of the waste material and the above-mentioned electrical problem, waste treatment did not start until the end of Day Two. All waste treatment runs were completed on schedule. The Soliditech equipment was demobilized on schedule. Site preparation, including setting up an office trailer, electrical and phone connection, and procuring and staging other auxiliary equipment, required three days. Site demobilization and restoration required four days after the equipment was removed.

Characteristics Influencing Performance

The Soliditech solidification/stabilization process has certain advantages and limitations. These are summarized below.

Contaminant Properties/Matrix Parameters

- The process is generally limited to treating wastes with a pH of 2 to 12. Waste material with a neutral pH is ideal for treatment. The pH of the untreated waste at the demonstration site ranged from 3.4 to 7.9.
- The process has upper limits to the amount of water or oil and grease that can be accommodated. These upper limits have not been accurately determined. If large amounts of these materials are present, adjustments to the amounts of additives must be made. Waste material treated during the demonstration contained up to 17 percent oil and grease and up to 58 percent water.
- The conditions imposed upon Soliditech during the demonstration did not allow optimum processing of waste, because each test run treated a different type of waste. Nevertheless, the process appeared to be relatively easy to run and moderately fast.
- The Soliditech process is able to solidify both solid and semi-solid materials. Solids such as rocks or other debris up to one foot in diameter can be accommodated by the process.
- The process should only be used when the ambient temperature is above freezing or when the treated material can be maintained at above-freezing temperatures during the first 24 hours after treatment. At lower temperatures the treated material may not adequately solidify. The temperature during the demonstration was above 35 degrees F during the day but below freezing at night. As a result, all samples and one TWM from each test run were allowed to cure in a heated warehouse at temperatures ranging from 50 to 70 degrees F. No differences in the integrity of these TWMs was noticed.

- It is difficult to assess when the treated material is adequately mixed. Some minor problems were observed during the demonstration. The initial batch of treated waste material (filter cake/oily sludge) was not totally blended, resulting in unmixed clumps of waste material in the solidified product.
- The long-term stability of the treated waste material is not known. U.S. EPA will monitor the solidified wastes for the next five years.

Equipment/Material Requirements

- The equipment required for the process is relatively simple and easily transported on two flatbed trailers. A dry solids storage hopper and a mixer are the two major pieces of equipment. The minimal electrical power requirements for transfer of cement or pozzolans from the hopper to the mixer can be met by a transportable generator. The mixer is self-powered by a diesel engine. During the demonstration, the equipment appeared to be problem-free.
- Accurately determining the weights of materials added to the mixer was required for the demonstration, but was found to be difficult. If this information is necessary for onemil operation, more sophisticated gauges and weight feeders could be added to the process; however, this would increase the system's complexity.
- Because the Soliditech process is a batch process, a number of batches must be run to treat large amounts of waste. Approximately 10 cubic yards of waste can be treated in an hour, once the equipment is set up and all reagents, additives, and waste materials are ready to be added to the mixer. During the demonstration, a total of 15 cubic yards of material was treated in four batches.
- The reagents and additives required for waste treatment are either readily obtainable (cement or pozzolans and water) or are required in relatively small amounts that can be readily shipped to the treatment location (Urrichem and the other additives).

Health and Safety Concerns

Both health and safety and community exposure concerns were assessed prior to the Soliditech demonstration. These concerns are discussed in this section.

Worker Safety

A site-specific Health and Safety Plan was prepared for the Soliditech SITE demonstration (PRC, 1988). This plan covered all work for the demonstration. The plan was approved by appropriate U.S. EPA and contractor health and safety personnel and reviewed by all personnel before they were allowed to work

at the site. The plan included a facility description, a list of chemicals of concern and their concentrations, health and safety zones, monitoring procedures and equipment, personnel safety procedures, personal protective equipment, decontamination procedures, hospital routes and personnel to contact in the event of an emergency, and a list of emergency equipment that was required during all site work. The health and safety plan was carefully followed during the demonstration. Daily health and safety briefings were held each morning to discuss any health or safety concerns.

In general, equipment operation is straightforward for the Soliditech technology. Safety requirements are the same as encountered during any activities involving heavy equipment and potentially hazardous chemicals. Operators are thoroughly trained in safe operating procedures and work habits, as well as in OSHA-mandated hazardous waste safety guidelines.

Community Exposure

Due to the nature of the contamination at the Imperial Oil Company/Champion Chemical Company site, community exposure was determined not to be a significant concern. The wastes to be treated during the demonstration contained very low levels of volatile organic compounds (VOCs). Soil was only excavated in one small area. This area was very remote and located more than 300 yards from the nearest dwelling. During excavation the soil in this area was moist, thus minimizing any dust. The soil was transported to the treatment area by a licensed solid waste hauler and accompanied by a New Jersey Department of Environmental Protection inspector. The two other wastes treated during the demonstration were obtained from the active area of the facility. One of these wastes was a waste oil containing low levels of VOCs. The other was an oil-saturated filter cake material. Monitoring instruments for both dust and **VOCs** were **constantly** used during all waste collection and transfer operations.

Section 4

Economic Analysis

One of the goals of the SITE Program is to develop reliable cost data for unique and commercially available hazardous waste treatment technologies. An economic analysis of the Soliditech technology calculated the cost to treat 5,000 cubic yards of contaminated waste using a 10-cubic yard capacity mixer at approximately \$152 per cubic yard. Labor and supplies were the major costs, accounting for approximately 33 and 41 percent, respectively, of the total cost.

Issues *and* Assumptions

This section summarizes the major issues and assumptions used to evaluate the cost of the Soliditech technology. In general, assumptions are based on information provided by Soliditech or from the actual costs incurred in planning and conducting the SITE technology demonstration. Certain assumptions were made to account for variable site and waste parameters as well as the non-representative nature of the cost of the demonstration on a waste unit basis. Some of the assumptions will undoubtedly have to be refined to reflect site-specific conditions.

Waste Volumes and Site Size

For the purposes of this analysis, the waste volume is assumed to be 5,000 cubic yards (approximately 5,000 tons) of contaminated soils. Contamination is assumed to extend to an average depth of 3 feet below the surface and cover an area of approximately 1 acre (43,560 square feet).

Major Technology Design and Performance Factors

The Soliditech technology is a batch operation, designed to treat 10 cubic yards of contaminated waste per batch. For the purposes of this analysis, it is assumed that eight batches (80 cubic yards) can be treated in a single mixer in an eight-hour shift -- allowing 10 minutes to load contaminated soils and reagents, 40 minutes to mix, and 10 minutes to unload the treated waste for each batch. It is further assumed that the mixer will be operated five days per week, resulting in a throughput rate of 400 cubic yards per week throughout the remedial action. Although Soliditech estimated a throughput of 100 cubic yards per mixer per day (Soliditech, 1989), we have used the lower figure of 80 cubic yards per day to allow for routine equipment maintenance, inclement weather, and reduced winter daylight, and to avoid shift differential labor costs for overtime. Using one mixer, it will take three months (13 weeks) to remediate the 5,000-cubic yard site.

Technology Operating Requirements

Nine people per day are assumed to be required to accomplish the remedial action: four to operate the process equipment; three to provide support in the field (such as sampling); and two to provide off-site support (such as data tabulation and reporting and administrative requirements). The four process personnel include two process operators, one supervisor, and one overall coordinator (Soliditech, 1989). Field support personnel will operate soil-moving equipment (loader, backhoe, dump truck, and forklift), coordinate site health and safety, and collect samples. This analysis assumes that the seven process and field support personnel will receive a per diem in addition to regular compensation. Off-site support personnel receive no per diem. Because it will take an estimated three months to remediate a 5,000-cubic yard site, the job may involve local hires. This analysis allows for three round trips home (one per month) for the nine on-site staff, including the initial and final travel to and from the site.

For every cubic yard of waste material processed during the Soliditech demonstration, the following amounts of materials were used:

- 1000 lbs cement
- 20 lbs Urrichem
- 30 lbs chemical additives

Water is used in the process and for decontamination, at a rate of 5000 gallons per day (gpd). Depending on site and waste variations, water usage may vary by plus or minus 20 percent.

Diesel fuel is used to run the Soliditech process as well as supporting equipment, at a rate of 15 gallons per hour. Because non-fuel utilities (such as trailer electricity and telephone) are not likely to average more than \$5 per day after mobilization (depending on climate), and potable water is costed separately for the process, these non-fuel utility costs will be neglected for this analysis.

Utilization Rates and Maintenance Schedules

As noted above, Soliditech claims that the throughput rate for a full-scale remedial action will reach 100 cubic yards per day per mixer. However, based on probable loading and mixing times, it seems unlikely that this rate can be sustained in an 8-hour day without overtime or shift differential costs. This analysis instead assumes a throughput rate of 80 cubic yards per day per mixer, at an effective utilization rate of 100 percent.

Maintenance would be performed outside a 40-hour week. (Alternatively, based on Soliditech's throughput estimate, a utilization rate of 80 percent would apply).

Costs Sensitive to Specific Wastes and Site Conditions

Because mixing accounts for two-thirds of the time spent in the Soliditech process, cost will presumably be unaffected by variations in waste type or site conditions. That is, there should be sufficient time between batches to collect 10 cubic yards of contaminated soils, regardless of waste variability. Furthermore, variability in site conditions, while potentially significant for short-term remedial actions, should not significantly affect costs for a remediation of three months. The variability of factors such as temporary storage, transportation, and off-site disposal of treated waste, on the other hand, will have a greater effect on cost.

Financial Assumptions

For the purposes of this analysis, it is assumed that financial factors (such as depreciation, interest rates, and non-process utility costs) will generally have a negligible effect on total treatment costs. This assumption has several bases. First, the Soliditech mixer will likely have little or no salvage value at the end of its three-year life cycle; therefore, a straight-line depreciation of \$21,667 per year for the mixer will be assumed. Second, the storage bins or tanks, compressor, pumps, and associated piping, which are valued together at \$6,000, are also assumed to be discarded at completion of the project and have no salvage value. Third, the depreciation of auxiliary support equipment, such as backhoes and dump trucks will be included in the cost of renting. For purchased equipment, depreciation costs will be negligible compared to the full cost of the remediation. Finally, in proportion to total site remediation costs, the loss of present value for working capital and contingency costs will be negligible. Therefore, interest rates will not be addressed.

Itemized Costs

Table 2, at the end of this section, itemizes the cost estimates for the Soliditech technology, using the assumptions already described. The itemized costs are further described below.

Site Preparation Costs

Site preparation costs include site design, surveys, legal searches, access rights, preparation for support facilities and auxiliary equipment (see below), and other costs. These preparation costs, exclusive of site development, are assumed to equal 500 staff hours at \$50/hr.

Permitting/Regulatory Costs

Permitting and regulatory costs may vary. The costs of complying with regulatory requirements and permitting will depend upon the nature of the site, its proximity to residential areas, and the state where it is located. Typical permitting and regulatory costs are estimated by Soliditech to be \$10,000 (Soliditech, 1989).

Equipment Costs

Capital Equipment Costs

According to Soliditech, "the capital cost value of the Soliditech mixer is \$65,000. The [mixer] has a 3-year life. In addition, storage bins or tanks for pozzolan, reagents, as well as a compressor for transferring pozzolan, pumps for the liquid, and associated piping and controls . was assumed to be a \$6,000 cost to the project, whether the equipment was purchased new or used or it was sold or discarded at project completion (Soliditech, 1989)." Since this analysis assumes that it will take 3 months using one mixer and associated equipment to remediate a 5,000-cubic yard site, the capital equipment will cost \$11,417.

Auxiliary Equipment

Auxiliary equipment includes such items as a support trailer or decontamination equipment that do not fall under the category of capital equipment costs. For example, although a dump truck is considered a major equipment item, it will not be considered a piece of capital equipment for this analysis.

Auxiliary equipment items may be divided into two categories: rental and purchased equipment. Because of the high cost of purchasing and transporting construction equipment, it is assumed that this equipment will be rented locally, near the site. The following rental equipment costs are assumed:

· Site Trailer	\$400/month
· Earthmoving equipment (backhoe and loader)	\$5,325/month
· Dump truck	\$2,400/month
· Forklift	\$1,950/month
· Tank truck	\$2,000/month
· Truck scale	\$1,200/month

Purchased equipment includes miscellaneous expendable materials (such as 55-gallon drums), and equipment that would be cheaper to buy than to rent. For instance, a steam cleaner, electric generator, and all necessary decontamination supplies (including fuel to run the generator) may be purchased for \$6,500. The life cycles of the generator and steam cleaner are assumed to be 1 year. It is assumed that this equipment will be used on other projects during its life cycle. Auxiliary equipment purchase costs are as follows:

• Miscellaneous Equipment (Dumpster, sludge pumps, plastic sheets, 55-gallon drums)	\$3,200/month
• Personnel Health & Safety Equipment (Disposable boots, gloves, protective clothing, etc.)	\$4,000/month
• Decontamination Equipment (Steam cleaner, generator, fluids)	\$6,500/year

Start-Up Cost

The start-up cost, including moving all equipment to the site, on-site mobilization, equipment setup, and preliminary chemical and physical testing, is estimated to be \$21,000.

Labor

As described above, nine people per day are required for the remediation. Labor costs are based on a 40-hour week, and are assumed to be \$40 per hour, including overhead and fringe benefits. In addition, seven of the nine people will receive a per diem of \$55 per day to cover the costs of meals and lodging. Since Soliditech envisions that its on-site people will be housed near the site, this per diem will apply for 28 days each month. Each on-site person will also be allowed one weekend of paid "home leave" per month, at a cost of \$500 in transportation per on-site person.

In addition to Soliditech personnel, some type of after-hours security service will be employed. This cost is assumed to be \$21 per hour for 60 hours per week.

An additional labor cost is training. Health and safety training costs were incurred by Soliditech and are not included in this cost estimate. Process and field support training is assumed to be 16 hours in duration per field staff.

Supplies and Consumables

The cost for materials is as follows:

• Cement	\$69/ton
• Urrichem	\$804/ton
• Chemical additives	\$1,340/ton

In addition, it is assumed that a 3-month supply of consumables and maintenance materials represents 10 percent of the cost of maintenance or 1 percent of the cost of capital equipment (\$71,000) per quarter. This corresponds to \$710 for a 3-month project.

Utilities

Water for processing and decontamination is assumed by Soliditech to cost \$5 per thousand gallons. This includes service fees associated with connect/disconnect or water transfer activities, and comes to \$125 per week. Fuel costs (at \$0.90/gal, 15 gal/hr) come to \$13.50/hour or \$540/week. As indicated earlier, the cost of telephone and electricity is assumed to be negligible. (Electricity for the steam cleaner is assumed to be provided by a portable generator, and is included in a separate cost category.)

Effluent Treatment and Disposal

It is assumed that one 55-gallon drum of equipment rinsate and decontamination solutions will be generated each week. It should be possible to recycle this liquid to the process. Another drum of disposable health and safety equipment will likely be

generated each week. The cost of disposal, including all manifest and transportation charges, is assumed to be \$500 per drum.

Shipping, Handling, and Transport of Residuals and Waste

On-site disposal is assumed. Off-site transport and disposal of 7,500 tons of treated waste (5,000 tons of waste plus more than 2,500 tons of cement and additives) would significantly increase the cost of treatment for the Soliditech technology. As part of on-site disposal, the auxiliary support equipment and personnel assigned to excavate and transfer waste would presumably develop and grade the site for disposal of the treated waste at no additional cost,

Analytical Costs

Two types of sampling and analysis are involved in the Soliditech process. Environmental sampling will be conducted as the waste is being excavated to assure that the waste removal is effective. Treated waste will also be sampled to demonstrate both the effectiveness of the treatment as well as the structural integrity of the solidified waste. Costs for data tabulation and sampling personnel have been included as labor costs.

This analysis assumes that one environmental sample will be collected every other day. Normally, a full scan for metals, volatile organic compounds, and semivolatile organic compounds would cost approximately \$1,200 per sample. However, an alternative "targeted" analysis for the site-specific hazardous constituents is assumed to be available at \$300 per sample, or \$750 per week. In addition, one QA/QC sample will be collected for each 20 environmental samples, and subjected to a full total waste analysis, at a cost of \$150 per week.

For sampling a treated waste, it is assumed that 5 percent of the batches will be sampled. Since the throughput rate for the process is 40 batches per week, two treated waste samples will be collected per week for both chemical and structural analysis. The cost for TCLP (or similar leaching) analysis is assumed to be \$750 per sample. The cost for testing for unconfined compressive strength is assumed to be \$50 per sample. The total cost for analyzing treated waste would thus be \$1,600 per week.

Facility Modifications/Repair/Replacement

Maintenance costs are assumed to be 10 percent of annual capital equipment costs (Soliditech, 1989). Since the cost of capital equipment is \$7,100 per year, the cost of maintenance will be \$7,100 per year or \$1,775 for the 3-month project.

Site Demobilization

The cost for site demobilization is assumed to be \$15,000. This includes final decontamination and removal of equipment, site cleanup and restoration, and installing a security fence, as well as any run-on/run-off or erosion control measures.

Table 2. Itemized Costs

Site Preparation		
	Subtotal	\$25,000
Permitting/Regulatory		
	Subtotal	\$10,000
Equipment		
Capital Equipment		
Mixer (\$65,000/36 mo)(3 mo)	5,417	
Ancillary Equipment (per job)	6,000	
	Subtotal	\$11,417
Auxiliary Equipment		
Site Trailer (\$400/mo)(3 mo)	1,200	
Backhoe & Loader (\$5,325/mo) (3 mo)	15,975	
Dump Truck (\$2,400 mo)(3 mo)	7,200	
Forklift (\$1,950/mo)(3 mo)		5,850
Tank Truck (\$2,000/mo)(3 mo)	6,000	
Truck Scale \$1200/mo)(3 mo)	3,600	
Miscellaneous Equipment		
(Dumpster, sludge pumps, plastic sheets, 55 gallon drums) (\$3,200/mo)(3 mo)	9,600	
Personnel Health & Safety Equipment		
(Disposable boots, gloves, protective clothing, etc.) (\$4000/mo)(3 mo)		12,000
Decontamination Equipment (steam cleaner, generator, fluids) (\$6,500/yr)(3 mo)		1,625
	Subtotal	\$ 63,050
Start-Up		
Miscellaneous Mobilization	5,000	
Preliminary Analytical		
Environmental (8 samples)(\$1200/sample)	9,600	
TCLP (8 samples)(\$750/sample)	6,000	
Unconfined Compressive Strength (8 samples)(\$50/sample)	400	
	Subtotal	\$ 21,000
Labor		
Process Operators (4)(\$40/hr)(40 hr/wk)(13 wks)	83,200	
Field Support (3)(\$40/hr)(40 hr/wk)(13 wks)	62,400	
Off-site Support (2)(\$40/hr)(40 hr/wk)(13 wks)	41,600	
Security (1)(\$21/hr)(60 hr/wk)(13 wks)	16,380	
Per diem (7)(\$55/day)(28 day/mo)(3 mo)	32,340	
Home Leave (7)(\$500/mo)(3 mo)	10,500	
Training (7)(16 hr)(\$40/hr)	4,480	
	Subtotal	\$250,900

(continued)

Table 2. (Continued)

Supplies and Consumables		
Cement (2,500 ton)(\$69/ton)	172,500	
Urrichem (50 ton)(\$804/ton)	40,200	
Chemical additives (75 ton)(\$1340/ton)	100,500	
Consumables	710	
	Subtotal	\$ 313,910
Utilities		
Fuel (\$540/wk)(13 wk)	7,020	
Water (\$125/wk)(13 wk)	1,625	
	Subtotal	\$ 8,645
Effluent Treatment and Disposal		
(1 drum/wk)(\$500/drum)(13 wk)	6,500	
	Subtotal	\$ 6,500
Residuals and Waste Shipping, Handling, and Transport		
	Subtotal	\$ 0
Analytical		
Environmental		
(2.5 samples/wk)(\$300/sample)(13 wk)		
Environmental QA/QC		
(2 samples)(\$1200/sample)	2,400	
TCLP (2 samples/wk)(\$750/sample)(13 wk)	19,500	
Unconfined Compressive Strength		
(2 samples/wk)(\$50/sample)(13 wk)	1,300	
	Subtotal	\$32,500
Facility Modifications/Repair/Replaement		
(\$7,100/yr)(0.25 yr)	1,775	
	Subtotal	\$1,775
Site Demobilization		
	Subtotal	\$15,000
	TOTAL	\$763,047

Note: This total corresponds to approximately \$152 per cubic yard of untreated waste, assuming on-site, in-place disposal. Off-site transport and disposal could significantly increase this cost.

References

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| <p>Federal Register 1986. Volume 51, No. 216, Appendix I to Part 268, November 1986.</p> <p>PRC, 1988. Demonstration Plan for the Soliditech, Inc., Solidification Process. Prepared for U.S. EPA, RREL, Cincinnati, Ohio, by PRC SITE Team, November 30, 1988.</p> <p>Soliditech, 1989. Economic Analysis of Soliditech SITE Project. Soliditech, Inc., March 23, 1989.</p> <p>U.S. EPA, 1986a. Prohibition on the Placement of Bulk Liquid Hazardous Waste in Landfills, Statutory Interpretative Guidance. U.S. EPA/530/SW86/016, 1986.</p> | <p>U.S. EPA, 1986b. Test Methods for Evaluating Solid Waste (SW-846). U.S. EPA Volumes IA, IB, IC, and II, Third Edition, U.S. EPA Document Control Number 955-001-00000-1, November 1986.</p> <p>U.S. EPA, 1989. Stabilization/Solidification of CERCLA and RCRA Wastes. U.S. EPA, RREL, Cincinnati, Ohio, EPA/625/6-89/022, May 1989.</p> <p>U.S. EPA, 1990. Technology Evaluation Report, SITE Program Demonstration Test, Soliditech, Inc. Solidification/Stabilization Process. U.S. EPA, RREL, Cincinnati, Ohio, U.S. EPA/540/5-89/005a, February 1990.</p> |
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Appendix A

Key Contacts

Additional information concerning the Soliditech process or the SITE program can be obtained from the following sources:

The Soliditech Technology

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President
Soliditech Inc.
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(713) 497-8558

The SITE Program

SITE Project Manager, Soliditech Demonstration

Dr. Walter E. Grube, Jr.
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Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7798

Director, Superfund Technology Demonstration Division

Robert Olexsey
U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
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SITE Program, EPA Headquarters

John Kingscott
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Office of Solid Waste and Emergency Response
401 M Street, S.W.
Washington, DC 20460
(202) 382-4362

Appendix B

Vendor Claims

[This appendix was prepared by the developer, Soliditech, Inc. according to guidance provided by U.S. EPA. These claims were evaluated during the SITE demonstration and are reported on in this application analysis.]

Applicability

Soliditech, Inc., was formed to apply the solidification process to field service remediation projects. The process was designed for use on a wide variety of industrial and hazardous wastes, and can be tailored to meet waste stabilization criteria such as TCLP, EP Toxicity, and other tests for both inorganic and organic waste streams.

Waste Types Compatible with Process

Bulk streams that have relatively high solids content, moderate amounts of organic material (particularly VOCs) and relatively high moisture content are appropriate for the process. The process is best suited for large volume, low toxicity, organic (API separator sludges, DAF sludges, tank bottoms) or inorganic (plating sludges, spent catalyst, **incinerator** ash) wastes. The treated waste is best suited to shallow land disposal or disposal in subterranean repositories. The process can handle a wide variety of waste streams of all types, including municipal waste water or water treatment sludges. The process is not limited by the physical state of the waste. Wastes can be delivered to the mixer by various methods, making both the solidification process as well as the waste handling and processing equipment very versatile.

Favorable Conditions for Execution of the Technology

Soliditech's transportable mixer units are designed to process solids, sludges, or liquids. The 10-cubic yard batch mixer unit is open-topped and easily accommodates most common waste transfer equipment. A smaller 2-cubic yard mixer accommodates drummed wastes and pumped materials for smaller projects. When necessary to control volatile emissions, the mixers can be covered during mixing with the internal air maintained under a slightly negative pressure and the exhaust filtered through a carbon canister to absorb vapors.

The Soliditech technology can be applied to industrial waste streams at operating facilities as well as for remediation of RCRA and CERCLA sites. The concurrent operation of two or more mixer units allows processing of larger volumes of wastes. Soliditech believes one mixing unit can efficiently

process approximately 15 to 20 yards of waste per hour. The amount of mixing ~~time~~ required depends on the homogeneity of the waste as well as the treatment standard to be met. The open-topped mixer allows continuous control over the degree of mixing. Uniform industrial waste streams at operating facilities may require a relatively short mixing time. CERCLA and other RCRA wastes may require a longer mixing time to assure high levels of homogeneity in the treated mixture and to provide a treated waste that meets leachate toxicity criteria.

Pre-treatment processes may include removing large debris, segregating incompatible waste types, and pretreating wastes containing high contents of oil and grease (preferably by mixing them with another compatible higher solids content waste stream such as contaminated soil, filter cake or spent catalyst).

Advantages of Process Equipment

The technology is a significant improvement over other solidification processes because the mixer design allows complete control over the consistency and degree of mixing (i.e., quality assurance). The open-topped design allows easy access for the mixer operator as well as the field chemist to evaluate mixing performance and to make adjustments as necessary prior to discharge of contents. This construction also allows easy decontamination and demobilization after use. The simple but rugged construction makes the process essentially unaffected by all but large debris. The support equipment is simple in construction and is largely available throughout the U.S.; this availability reduces the associated costs for projects located some distance from the Soliditech offices.

Equipment lifetime (three to five years) far exceeds normal project durations. The mixer and associated units have proven to be very reliable; there are no revitalization or replacement requirements other than normal machine maintenance. The processing equipment can be easily transported to operating facilities or can be designed for permanent on-site installations, if desired.

The primary equipment consists of the mixer unit and the reagent/additive tanks mounted on a low-boy trailer; this equipment is fully transportable and requires no assembly/disassembly. A cement or pozzolan storage silo (which can be simply off-loaded and set upright) with a capacity of up to 15 cubic yards can also be transported to a remote site; or if it is more feasible, a cement silo can be obtained locally. The mixer unit is self-contained and uses a diesel-powered engine; the

pozzolan or cement transfer equipment can also be operated by a portable compressor. External power sources are thus not required, operations can easily be conducted at remote locations.

Pozzolan or cement and water storage facilities are usually located remote to the mixer and do not generally require decontamination. The recommended enclosed steel tanks are easily cleaned if necessary using conventional pressure/steam cleaning equipment. The mixer discharge chute facilitates the collection of washwater for containment, treatment or disposal.

Equipment operation is straightforward. Safety requirements are the same as encountered during any activities involving heavy equipment and potentially hazardous chemicals. Operators are thoroughly trained in safe operating procedures and work habits, as well as in OSHA-mandated hazardous waste safety guidelines.

Remediation Project Schedule

Based on the results of the SITE demonstration, a project schedule for processing a similar waste was developed. The oily filter cake material processed for the demonstration was selected as a representative waste. This material had a soil-like consistency and contained approximately 17 percent (by weight) petroleum hydrocarbons in the matrix. The mix design for this material contained 58.6 percent waste, 25.8 percent Type II Portland cement, 14.1 percent water; 0.9 percent additives and 0.6 percent Urrichem. Soliditech believes that, for a typical project treating approximately 5,000 cubic yards of waste, using one mixer unit (or multiple mixer units to accelerate productivity) at a production rate of 20 yards per hour, site requirements would include:

- A work area for the mixer unit of 30 x 100 feet
- A pozzolan or cement storage area 30 x 100 feet
- A compressor station 10 x 10 feet
- A field office/equipment storage area 20 x 40 feet
- A decontamination/waste water storage area 20 x 30 feet
- A vehicle parking/storage area 15 x 40 feet
- A two-cubic yard front-end loader or other waste delivery equipment
- A 100 cfm diesel-powered compressor
- A mobile steam cleaner
- Poly-pak drums to store contaminated clothes etc., for later disposal
- Sampling equipment

Mobilization is assumed to be authorized when all contractual negotiations have been completed and any regulatory questions answered. The following table summarizes total project duration, which includes non-productive weekends.

<u>Description</u>	<u>Days</u>
1. Mobilization/preparation/setup	2
2. Project work days (at 160 yards/day)	32
3. Non-productive days	12
4. Decontamination/break down	
5. Demobilization	<u>1</u>
	48

Cost Information

The Soliditech process equipment is highly mobile and transportable. Semi-permanent installations operations can also be easily designed and achieved using essentially the same equipment. The mixing unit, which is the primary piece of equipment used with the process, is normally mounted on a conventional low-boy trailer hauled by a conventional trailer tractor unit.

The cost of the Soliditech mixing unit, complete with a diesel power unit and hydraulically operated lifting legs, is \$65,000. The tractor/trailer combination is about \$85,000; the silo about \$5,000; and miscellaneous tanks/pumps, etc., total \$1,000. These items constitute the major direct capital cost items. Certain indirect capital costs can also be included, as well as certain nondepreciable capital costs. Examples of indirect costs include administration, permits and contingencies. Nondepreciable items include developing **operating** procedures, training programs, and working capital requirements.

Operating costs include variable, semivariable and fixed costs. Variable costs are essential raw materials costs of the process and power/fuel costs of the equipment and are related to time of operation and/or throughput of the equipment. Raw materials, particularly pozzolans or cement, have the greatest variability -- not only as to the type of material (i.e., Portland cement versus fly ash) but also with the particular formulation for the waste streams. Pozzolans, kiln dust, and cement typically vary between \$25/ton to \$70/ton delivered, depending on site location and the availability of these materials in the area. Reagent cost (Urrichem) is \$5/gallon, in small quantities, and other special additives **may** range up to \$2/pound. These special additives are non-typical and are not included in this discussion.

Semivariable costs include labor, maintenance, special equipment rental or consumables (i.e., personnel protective gear), and mobilization/decontamination/demobilization costs. Mobilization costs include site preparation, logistics, personnel, equipment material and set-up costs. Labor cost, typically can vary between \$10 and \$20/hour for equipment operators, laborers. Supervisors' rates can vary between \$25 and \$30/hour, as do rates for a site coordinator and chemical technician. Maintenance and consumable **costs are** best reflected as flat day rate allocation. Transportation (including labor) is set at \$2.50/mile.

Finally, certain fixed costs include insurance costs, depreciation or capital equipment and various taxes. These three items for a single unit set-up can be estimated as \$350/day in total.

Certain items are generally not accounted for in establishing costs for the process. These include analytical costs, efflu-

ent treatment or disposal, waste shipping or handling and any special permitting or compliance costs. These costs are treated as special or extraordinary items and are charged to the project as special costs.

Appendix C

SITE Demonstration Results

Appendix C summarizes the Soliditech SITE demonstration results and briefly describes related applications.

Site Characteristics

The Imperial Oil Company/Champion Chemical Company Super-fund site in Morganville, New Jersey was chosen for the demonstration. Past activities at the site include chemical processing and oil reclamation. The active area of the site is presently used by an oil blending and repackaging facility. Contamination is present at the site in soil, a waste filter cake pile, and an abandoned storage tank, as well as in the ground water.

Waste Description

The chemicals of concern at this site include metals, such as arsenic, chromium, copper, lead, nickel, and zinc; and various organic chemicals, including polychlorinated biphenyls (PCBs) and petroleum hydrocarbons.

Three types of contaminated waste material were treated during the demonstration--soil, waste filter cake material from a site waste pile, and oily sludge. The contaminated soil and filter cake were treated directly. To aid in treatment, the oily sludge was mixed with additional filter cake material before treatment.

Untreated and treated waste samples were collected for each test parameter from each of these three waste materials. The samples were analyzed for chemical constituents and physical characteristics and were subjected to leaching/extraction testing. The results were used to compare the physical and chemical properties of the treated and untreated waste, and determine the effectiveness of the treatment process. The detailed results and operating summaries are contained in the Technology Evaluation Report (U.S. EPA, 1990).

Waste Treatment Formulations

The waste treatment formulation used by Soliditech include Portland cement, Unichem, proprietary additives, and water--all blended with the waste material. Figure C-1 depicts the treatment formulations (weight percent) used by Soliditech to treat the three waste types that were solidified during the demonstration. Pure sand was also treated to determine the concentrations of analytes of concern originating from the Soliditech reagent, additives, and cement. The mixture of sand, reagent, additives, and cement is referred to as the reagent

mixture. The pure sand was first analyzed separately to determine its contribution to the analytes found in the reagent mixture.

Physical Properties of the Wastes

Physical tests were performed on both untreated and treated waste samples. The treated wastes were tested after a 28-day curing period. Some of the physical tests were not appropriate for the untreated waste (unconfined compressive strength [UCS] wet/dry durability, freeze/thaw durability, permeability) or the treated waste (particle size analysis).

The physical test results showed that the Soliditech process is capable of solidifying waste material with up to 17 percent oil and grease content. The process produced structurally firm material.

The UCS of the treated samples ranged from 390 psi for filter cake to 860 psi for filter cake/oily sludge mixture. After 12 cycles of wet/dry and freeze/thaw testing, UCS tests were performed on the residual treated material. The results of this testing showed that the compressive strength of the treated waste was significantly diminished. However, UCS values meet the U.S. EPA guideline of at least 50 psi (U.S. EPA, 1986).

The permeability, wet/dry durability, and freeze/thaw durability properties for the treated wastes were also good. The permeability values ranged from 8.9×10^{-9} to 4.5×10^{-7} cm/sec, which lie mostly below the U.S. EPA guideline of 10^{-7} for hazardous waste landfill soil barrier liners (40 CFR Part 264, Subpart N). The wet/dry durability tests indicated less than one percent weight loss after 12 wet/dry cycles. No significant weight loss occurred as a result of 12 freeze/thaw cycles.

The bulk density of the waste increased from 25 (filter cake) to 41 percent (filter cake/oily sludge) due to the treatment process. The increase in volume of the waste due to treatment ranged from no increase (contaminated soil) to 59 percent (filter cake/oily sludge mixture), with an average increase of approximately 22 percent. The values for the increase in volume are considered to be approximate due to difficulties in accurately measuring the weight or volume of the raw waste and cement. Using the average value for volume increase, each cubic yard of contaminated waste would result in approximately 1.22 cubic yards of treated waste.

Table C-1 summarizes the physical properties of the untreated and treated waste materials from the demonstration.

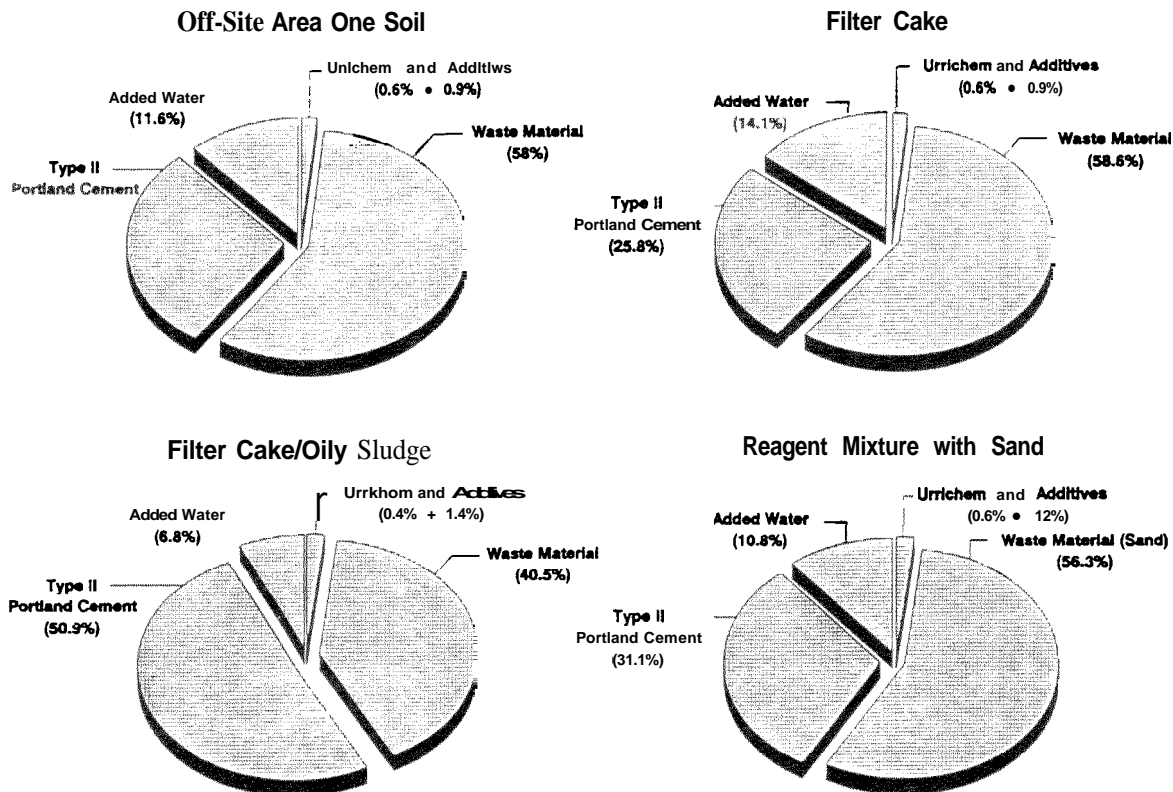


Figure C-1. Soliditech Treatment Formulations

Chemical Properties of the Wastes

Both untreated and treated wastes were chemically analyzed for metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and oil and grease. The treated waste was analyzed after a 28-day curing period. The results, given in Table C-2, are based upon total waste analysis. A reduction in analyte concentration after treatment can partially be attributed to the dilution of the waste with cement, water reagent, and additives. Any increase in analyte concentration may be attributed either to materials in the cement, water reagent, or additives; or to chemical or physical changes as a result of the treatment process. Total waste analyses detected PCBs, arsenic, aluminum, barium, beryllium, cadmium, chromium, copper, lead, nickel, and zinc in most of the untreated and treated waste samples. Several VOCs were detected in the untreated but not treated waste samples and several phenols (SVOCs) were detected in the treated but not the untreated wastes.

As previously mentioned, pure sand was used to form the reagent mixture. Analysis of the pure sand used for the reagent mixture showed the presence of arsenic, chromium, copper, lead, nickel, and zinc. Table C-3 summarizes these results.

TCLP, EP Toxicity, and BET extraction tests were run on the untreated and treated waste samples. Extraction tests grind the untreated or treated waste samples to a specified size and then extract contaminants from the waste material over a

specified period of time. The extracts are then chemically analyzed. ANS 16.1 and WILT leaching tests were run on the treated waste samples. Leaching tests place the monolithic waste in the specified leaching fluid for a specified period of time. The leachates are then chemically analyzed.

Extracts of the untreated and treated waste were generated by the TCLP, EP Toxicity, ANS 16.1 (treated waste only), BET, and WILT extraction or leaching procedures. All extracts were analyzed for metals, PCBs, and oil and grease. The TCLP extract was also analyzed for VOCs and SVOCs. The results of these analyses are summarized in Tables C-4 through C-13.

Table C-4 summarizes the chemical analyses of the TCLP extracts generated from the untreated and treated waste materials. Analyses of extracts of both the untreated and treated wastes showed no detectable amounts of PCBs. Lead concentrations of as much as 5.4 mg/L were found in the TCLP extracts of the untreated wastes, but were reduced to 0.01 mg/L or less by the treatment process. Arsenic was present at up to 0.19 mg/L in the untreated waste and 0.017 mg/L in the treated waste from Off-Site Area One. Cadmium, nickel, and zinc were reduced to below their respective detection limits due to treatment. Aluminum, barium, and chromium were found in two or three of the treated waste samples, as well as the reagent mix sample.

The results of the EP Toxicity (Table C-5) and BET extraction tests (Tables C-6 through C-9) showed similar reductions in metal concentrations. The analytes generated by

these procedures were not analyzed for VOCs or SVOCs. Analyses of these extracts yielded results below the detection limits for PCBs (from 0.10 to 0.90, depending upon Aroclor and sample matrix) in both the untreated and treated waste samples.

The ANS 16.1 and WILT leaching tests simulate leaching from a solidified mass. Results of these tests (Tables C-10 through C-13) showed low concentrations of metals and no PCBs leaching from the solidified waste. Oil and grease concentrations in these leachates were also less than those in the TCLP extracts.

Placement of Treated Wastes

After the treatment process, the treated wastes were allowed to cure at the site for the prescribed 28-day curing period. The chemical and physical nature of the treated material is not

anticipated to change significantly past the 28-day curing period.

Samples of the solidified soil were allowed to cure on-site in a heated warehouse. The post-treatment solidified samples were used to determine the physical, chemical, and leaching characteristics of the stabilized wastes.

The remainder of the treated waste was placed in one-cubic yard plywood' forms. The treated waste in the forms was allowed to cure for 28 days before the forms were uncrated and prepared for long-term storage. The treated waste monoliths (TWMs) were placed in a closely formed stack that was wrapped in 40-mil thick high-density polyethylene (HDPE) film for protection. Periodically, the TWMs will be unwrapped and examined as part of the long-term monitoring. Figure C-2 depicts the placement of the TWMs in the closely formed stack.

Table C-1. Physical Properties

	<u>Filter Cake</u>		<u>Filter Cake/Oily Sludge Mixture</u>		<u>Off Site Area One</u>	
	<u>Untreated</u>	<u>Treated^(a)</u>	<u>Untreated</u>	<u>Treated^(a)</u>	<u>Untreated</u>	<u>Treated^(a)</u>
Bulk Density (g/cm ³)	1.14	1.43	1.19	1.68	1.26	1.59
Permeability (cm/sec)	NA ^(b)	4.53 x 10 ⁻⁷	NA	8.93 x 10 ⁻⁹	NA	3.41 x 10 ⁻⁸
Unconfined Compressive Strength (psi)						
Initial ^(c)	NA	390	NA	860	NA	680
Post Testing ^(d)	NA	121	NA	220	NA	198
Post-Testing ^(e)	NA	114	NA	290	NA	190
Loss on Ignition (%)	54	41	70	34	36	34
Water Content (%)	28.7	21.0	58.1	14.7	23.5	12.6
Particle Size (mean in mm)	0.32	NA	0.46	NA	0.42	NA
Wet/Dry	NA	<1	NA	<1	NA	<1
Weathering (% wt. loss)						
Freeze/Thaw Weathering (% wt. loss)	NA	<1	NA	≤1	NA	<1

Notes:

a Treated waste sampled after a 28-day curing period.

b NA = Not analyzed.

c Measured after 28-day curing period.

d Measured after 12 cycles of Wet/Dry testing.

e Measured after 12 cycles of Freeze/Thaw testing.

Table C-2. Chemical Analyses of Untreated and Treated Waste

	<u>Filter Cake</u>		<u>Filter Cake/Oily Sludge Mixture</u>		<u>Off-Site Area One</u>		<u>Reagent MIX</u>
	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	
Volatile Organic Compounds (mg/Kg)							
Ethyl Benzene	<1.5	<1.5	4.3	<2.2	<1.5	<1.5	NA
Tetrachloroethene	<1.5	<1.5	1.6	<1.5	<1.5	<1.5	NA
Toluene	<1.5	<1.5	8.4	<4.9	8.3	<7.9	
Trichloroethene	<1.5	<1.5	3.3	<2.2	<1.5	<1.5	NA
Xylenes	<1.5	<1.5	32	<18	2.2	<2.2	NA
Semivolatile Organic Compounds (mg/Kg)							
Butyl benzyl phthalate	<10	<5.0	49	<3.3	49	4.3	<1.0
o-Cresol	<10	<5.0	<10	<3.3	<5.0	<3.3	<1.0
p-Cresol	<10	14	<10	4.4	<5.0	<3.3	<1.0
2,4-Dimethylphenol	<10	<5.0	<10	3.7	<5.0	<3.3	<1.0
Bis(2-Ethylhexyl) phthalate	<10	10	<10	<3.3	24	8.2	<1.0
2-Methylnaphthalene	<10	<5.0	14	4.4	6.2	3.8	<1.0
Naphthalene	<10	<5.0	<10	<3.3	<5.0	<3.3	<1.0
Phenol	<10	12	<10	4.8	<5.0	<3.3	<1.0
PCBs(mg/Kg)							
Aroclor-1242	9.3	6.3	16	6.2	29	33	<0.0020
Aroclor-1260	19	10	27	8.4	14	7.5	<0.0040
Metals (AA) (mg/Kg)							
Arsenic	26	28	14	40	94	92	59
Mercury	<0.040	<0.040	<0.040	<0.040	0.16	0.17	<0.040
Selenium	<0.20	<0.20	<0.20	<0.20	0.23	<0.20	<0.20
Thallium	0.17	0.15	0.052	0.12	<0.050	<0.10	0.17
Metals (ICPES) (mg/Kg)							
Aluminum	8,400	17,000	5,500	18,000	4,000	11,000	22,000
Barium	1,900	780	1,600	1,000	700	580	1,700
Beryllium	0.17	<0.10	0.13	0.23	0.23	<0.10	0.54
Cadmium	0.37	0.50	1.0	1.0	1.5	0.70	1.2
Calcium	1,000	110,000	1,200	190,000	4,600	150,000	180,000
Chromium	4.7	20	5.7	28	11	29	38
Copper	21	28	34	43	33	43	60
Lead	2,200	680	2,500	850	650	480	20
Nickel	2.7	11	3.0	16	2.7	13	21
Sodium	83	430	950	1,800	93	480	2,500
Zinc	26	23	150	54	120	95	39
Other Chemical Tests							
Eh (mv)	370	-31	220	-45	100	-63	-60
Oil and Grease, infrared (mg/Kg)	170,000	77,000	130,000	60,000	28,000	46,000	NA
pH (pH units)	3.4	11.8	3.6	12.0	7.9	12.0	12.1

NA: Not Analyzed

Table C-3. Chemical Analysis of Sand

Metals (AA)	(mg/Kg)
Arsenic	0.11
Mercury	<0.050
Selenium	<0.20
Thallium	<0.20
Metals (ICPES)	(mg/Kg)
Aluminum	110
Barium	<1.0
Beryllium	<0.20
Cadmium	<0.50
Calcium	<100
Chromium	<3.0
Copper	<2.0
Lead	<5.0
Nickel	<2.0
Sodium	<100
Zinc	<2.0

Note: Sand was used as a waste surrogate in the reagent mix test run.

Table C-4. Chemical Analyses of TCLP Extract from Untreated and Treated Waste Materials

	<u>Filter Cake</u>		<u>Sludge Mixture</u>		<u>Off-Site Area One</u>		<u>Reagent Mix</u>
	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	
Volatile Organic Compounds (µg/L)							
Acetone	250	<210	1000	<820	200	<160	0.058
Benzene	<2.0	<2.0	8.2	<4.6	<2.0	<2.0	<0.0020
2-Butanone	<10	<10	29	<10	<10	<10	0.011
Ethyl benzene	<2.0	<2.0	8.9	<3.7	4.7	<3.0	<0.0020
4-Methyl-2-pentanone	4.3	<2.0	60	<55	370	<8.4	0.069
Methylene chloride	13	<10	21	<18	<10	<10	<0.010
Tetrachloroethene	<2.0	<2.0	2.9	<2.0	<2.0	<2.0	<0.0020
Toluene	<2.0	<2.0	55	<24	270	<110	0.047
1,1,1-Trichloroethane	4.0	<2.0	<2.0	<2.0	<2.0	<2.0	<0.0020
Trichloroethene	<2.0	<2.0	27	<13	<2.0	<2.0	<0.0020
Xylenes	<2.0	<2.0	57	<14	26	<8.2	0.012
Semivolatile Organic Compounds (µg/L)							
Benzyl alcohol	<10	<19	<10	<10	57	72	<10
Butyl benzyl phthalate	<10	<10	<10	<10	36	<10	<10
o - C r e s o l	<10	62	44	88	18	13	<10
p-Cresol	<10	440	47	340	<10	110	<10
2,4-Dimethylphenol	<10	20	93	130	10	26	<10
Phenol	<10	630	200	340	<10	100	<10
PCBs (µg/L)							
Aroclor-1242	<0.42	<0.45	<0.43	<0.11	<0.42	<0.44	<0.11
Aroclor-1260	<0.84	<0.90	<0.86	<0.21	<0.84	<0.87	<0.22
Metals (AA) (mg/L)							
Arsenic	0.0050	<0.0020	0.014	<0.0020	0.19	0.017	<0.0020
Lead	NA	0.0020	NA	0.014	0.55	0.012	NA
Metals (ICPES) (mg/L)							
Aluminum	0.50	<0.20	0.28	0.47	0.60	0.40	0.77
Barium	1.4	1.3	2.5	5.1	1.6	2.3	4.0
Cadmium	0.0052	<0.0050	0.0093	<0.0050	<0.0050	<0.0050	<0.0050
Calcium	9.0	1,800	21	1,900	190	1,900	1,900
Chromium	<0.030	0.063	<0.030	<0.030	<0.030	0.040	0.063
Copper	0.040	0.023	0.023	<0.020	<0.020	0.037	<0.020
Lead	4.3	<0.20	5.4	<0.050	0.46	<0.050	<0.050
Nickel	<0.020	<0.020	0.027	<0.020	0.033	<0.020	<0.020
Sodium	1,100	13	1,200	43	1,200	16	34
Zinc	0.26	<0.020	1.3	<0.020	0.63	<0.020	<0.020
Other Chemical Tests							
Eh (mv)	270	-28	210	-35	190	-57	-23
Filterable Residue (TDS) (mg/L)	4,500	8,500	5,200	8,600	6,300	9,000	8,600
Oil & Grease, infrared (mg/L)	1.4	4.4	1.6	2.4	1.9	12	<0.40
pH (pH units)	4.6	10.8	4.8	11.6	5.1	1.5	11.4

NA: Not Analyzed

Table C-5. Chemical Analyses of EP Extract from Untreated and Treated Waste

	<u>Filter Cake</u>		<u>Filter Cake/Oily Sludge Mixture</u>		<u>Off-Site Area One</u>		<u>Reagent Mix</u>
	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	
PCBs (µg/L)							
Aroclor-1242	<0.43	<0.41	<0.43	<0.42	<0.45	<0.21	<0.020
Aroclor-1260	<0.86	<0.82	<0.86	<0.84	<0.90	<0.42	<0.040
Metals (AA) (mg/L)							
Arsenic	0.010	0.0023	0.011	0.0020	0.18	0.028	<0.0020
Lead	0.26	0.0023	0.55	0.015	0.12	0.012	<0.0020
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020
Selenium	<0.0040	<0.0040	<0.0040	<0.0050	<0.0040	<0.0050	0.017
Thallium	<0.0010	<0.0010	0.0013	<0.0010	<0.0010	<0.0010	<0.0010
Metals (ICPES) (mg/L)							
Aluminum	<0.20	<0.20	<0.20	<0.20	0.40	0.20	0.50
Barium	0.21	1.4	1.1	5.7	0.58	2.4	4.3
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Cadmium	<0.0050	<0.0050	0.0082	<0.0050	0.0052	<0.0050	<0.0050
Calcium	4.8	2,000	11	2,100	140	2,100	1,900
Chromium	<0.030	0.083	<0.030	0.037	<0.030	<0.030	0.067
Copper	<0.020	0.037	<0.020	<0.020	<0.020	0.060	<0.020
Lead	0.25	<0.050	0.52	<0.050	0.067	<0.050	<0.050
Nickel	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Sodium	1.4	15	58	45	2.1	16	35
Zinc	0.032	<0.020	0.86	<0.020	0.26	<0.020	<0.020
Other Chemical Tests							
Eh (mV)	320	-2.0	220	-30	130	-10	9.0
Filterable Residue (IDS) (mg/L)	90	9,500	330	9,100	790	9,400	8,700
Oil & Grease, infrared (mg/L)	<0.40	4.0	<0.40	3.1	2.6	11	<0.40
pH (pH units)	3.8	10.9	4.8	11.8	4.8	11.7	11.3

Table C-6. Chemical Analysis of BET Extract from Untreated and Treated Filter Cake Waste

	1:4		<u>Solid-to-Liquid Ratio</u> 1:20		1:100	
	Untreated	Treated	Untreated	Treated	<u>Untreated</u>	<u>Treated</u>
PCBs (µg/L)						
Aroclor-1242	<0.42	<0.43	<0.41	<0.41	<0.42	<0.21
Aroclor-1260	<0.84	<0.86	<0.82	<0.82	<0.84	<0.42
Metals (AA) (mg/L)						
Arsenic	0.072	0.011	0.014	0.0037	0.020	0.0020
Mercury	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020
Selenium	<0.0050	<0.0040	<0.0050	<0.0040	<0.0050	<0.0040
Thallium	<0.0020	<0.0010	<0.0020	<0.0010	<0.0020	<0.0010
Metals (ICPES) (mg/L):						
Aluminum	1.9	0.20	0.23	0.47	0.37	1.1
Barium	0.14	6.3	0.28	3.4	0.47	0.92
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Cadmium	0.0073	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Calcium	30	850	7.3	480	1.2	230
Chromium	<0.030	0.046	<0.030	0.037	<0.030	<0.030
Copper	0.050	0.063	<0.020	0.027	<0.020	<0.020
Lead	0.87	<0.050	0.42	<0.050	0.18	<0.050
Nickel	0.063	<0.020	<0.020	<0.020	<0.020	<0.020
Sodium	2.3	84	<1.0	19	<1.0	4.3
Zinc	0.27	<0.020	0.047	<0.020	0.020	<0.020
Other Chemical Tests						
Eh (mV)	270	-82	290	-92	270	-82
Filterable Residue						
(TDS) (mg/L)	440	3,800	120	1,700	40	760
Oil & Grease, infrared (mg/L)	0.65	6.3	0.53	2.7	<0.40	<0.40
pH (pH units)	3.7	11.7	3.5	11.7	3.9	11.5
Total Organic Carbon (mg/L)	91	140	28	43	11	14

Table C-7. Chemical Analysis of BET Extract from Untreated and Treated Filter Cake/Oily Sludge Mixture

	<u>1:4</u>		Solid-to-Liquid Ratio <u>1:20</u>		<u>1:100</u>	
	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>
PCBs (µg/L)						
Aroclor-1242	<1.1	<0.42	<0.44	<0.42	<0.41	<0.22
Aroclor-1260	<2.2	<0.84	<0.88	<0.84	<0.82	<0.44
Metals (AA) (mg/L)						
Arsenic	0.042	0.0080	0.035	0.0023	0.0083	0.0030
Mercury	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020
Selenium	<0.0050	<0.0040	<0.0050	<0.0040	<0.0050	<0.0040
Thallium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Metals (ICPES) (mg/L)						
Aluminum	0.36	0.23	<0.20	0.43	<0.20	1.3
Barium	0.83	17	0.78	9.6	0.48	2.6
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Cadmium	0.036	<0.0050	0.0062	<0.0050	<0.0050	<0.0050
Calcium	44	730	9.1	750	2.1	440
Chromium	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Copper	<0.020	0.030	<0.020	0.023	<0.020	<0.020
Lead	1.7	<0.050	0.43	<0.050	0.14	<0.050
Nickel	0.049	0.023	0.028	<0.020	0.022	<0.020
Sodium	230	250	80	58	17	13
Zinc	2.7	<0.020	0.69	<0.020	0.16	<0.020
Other Chemical Tests						
Eh (mV)	240	-101	220	-99	220	-93
Filterable Residue (TDS) (mg/L)	1,800	3,500	470	2,300	110	1,200
Oil & Grease, infrared (mg/L)	3.2	4.9	2.2	1.3	1.3	0.43
pH (pH units)	3.7	12.0	4.2	11.9	4.4	11.8
Total Organic Carbon (mg/L)	200	110	60	32	21	8.0

Table C-8. Chemical Analysis of BET Extract from Untreated and Treated Off-Site Area One Waste

	Solid-to-Liquid Ratio					
	<u>1:4</u>		<u>1:20</u>		<u>1:100</u>	
	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>	<u>Untreated</u>	<u>Treated</u>
PCBs (µg/L)						
Aroclor-1242	<1.1	<0.43	<1.1	<0.21	<0.43	<0.10
Aroclor-1260	<2.3	<0.86	<2.2	<0.42	<0.86	<0.20
Metals (AA) (mg/L)						
Arsenic	0.38	0.067	0.29	0.022	0.19	0.0097
Mercury	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020	<0.00020
Selenium	<0.0040	0.0070	<0.0040	0.0060	<0.0040	<0.0040
Thallium	<0.0010	<0.0020	<0.0010	<0.0020	<0.0010	<0.0020
Metals (ICPES) (mg/L)						
Aluminum	<0.20	<0.20	<0.20	<0.20	0.69	0.83
Barium	0.11	9.7	0.047	5.5	0.023	1.4
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Cadmium	0.0068	<0.0050	0.0055	<0.0050	<0.0050	<0.0050
Calcium	150	1,000	58	860	19	410
Chromium	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Copper	<0.020	0.17	<0.020	0.057	<0.020	0.020
Lead	<0.050	<0.050	<0.050	0.090	<0.050	<0.050
Nickel	<0.020	0.033	<0.020	<0.020	<0.020	<0.020
Sodium	5.0	80	2.2	19	1.1	4.0
Zinc	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Other Chemical Tests						
Eh (mV)	110	-77	150	-78	100	-50
Filterable Residue (TDS) (mg/L)	1,100	4,600	390	2,600	330	980
Oil & Grease, infrared (mg/L)	16	26	12	15	4.4	3.7
pH (pH units)	8.3	12.1	8.6	12.1	9.0	11.8
Total Organic Carbon (mg/L)	190	120	73	54	30	14

Table C-9. Chemical Analyses of BET Extract from Reagent Mix

	<u>Solid-to-Liquid Ratio</u>		
	<u>1:4</u>	<u>1:20</u>	<u>1:100</u>
PCBs (µg/L)			
Aroclor-1242	<0.11	<0.11	<0.11
Aroclor-1260	<0.22	<0.22	<0.22
Metals (AA) (mg/L)			
Arsenic	0.0030	0.0037	0.0073
Mercury	<0.00020	<0.00020	<0.00020
Selenium	<0.0020	<0.0020	<0.0020
Thallium	<0.0020	<0.0020	<0.0020
Metals (ICPES) (mg/L)			
Aluminum	0.37	1.8	4.8
Barium	27	10	1.6
Beryllium	<0.0020	<0.0020	<0.0020
Cadmium	<0.0050	<0.0050	<0.0050
Calcium	540	560	210
Chromium	<0.030	<0.030	<0.030
Copper	<0.020	<0.020	<0.020
Lead	<0.050	<0.050	<0.050
Nickel	<0.020	<0.020	<0.020
Sodium	160	39	9.0
Zinc	<0.020	<0.020	<0.020
Other Chemical Tests			
Eh (mV)	-69	-80	-71
Filterable Residue (TDS)(mg/L)	2,900	1,700	620
Oil & Grease, infrared (mg/L)	<0.50	<0.50	<0.40
pH (pH units)	12.0	12.0	11.8
Total Organic Carbon (mg/L)	36	9.7	3.0

Table C-10. Chemical Analyses of ANS 16.1 Leachate from Treated Filter Cake Waste

	<u>DAY 1</u>	<u>DAY 3</u>	<u>DAY 7</u>	<u>DAY 14</u>	<u>DAY 28</u>
PCBs (µg/L)					
Aroclor-1242	<0.11	<0.10	<0.11	<0.020	<0.11
Aroclor-1260	<0.21	<0.21	<0.22	<0.040	<0.22
Metals (AA) (mg/L)					
Arsenic	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Mercury	<0.00030	<0.00020	<0.00030	<0.00020	<0.00020
Selenium	<0.0040	<0.0040	<0.0050	<0.0040	<0.0040
Thallium	<0.0020	<0.0020	<0.0020	<0.0010	<0.0020
Metals (ICPES) (mg/L)					
Aluminum	<0.20	0.27	0.30	<0.20	0.37
Barium	0.17	0.19	0.22	0.25	0.28
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Cadmium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Calcium	63	63	72	81	100
Chromium	<0.030	<0.030	<0.030	<0.030	<0.030
Copper	<0.020	<0.020	<0.020	<0.020	<0.020
Lead	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel	<0.020	<0.020	<0.020	<0.020	<0.020
Sodium	7.3	5.2	4.4	5.3	5.0
Zinc	<0.020	<0.020	<0.020	<0.020	<0.020
Other Chemical Tests					
Eh (mV)	-20	-15	-36	-41	-57
Filterable Residue (TDS) (mg/L)	310	270	310	340	490
Oil & Grease, infrared (mg/L)	<0.40	<0.40	<0.50	<0.40	<0.40
pH (pH units)	10.7	10.9	11.0	10.7	11.3
Total Organic Carbon (mg/L)	6.6	5.2	5.3	6.3	7.0

Table C-11. Chemical Analyses of ANS 16.1 Leachate from Treated Filter Cake/Oily Sludge Mixture

	<u>DAY 1</u>	<u>DAY 3</u>	<u>DAY 7</u>	<u>DAY 14</u>	<u>DAY 28</u>
PCBs (µg/L)					
Aroclor-1242	<0.11	<0.10	<0.11	<0.020	<0.10
Aroclor-1260	<0.21	<0.20	<0.22	<0.040	<0.20
Metals (AA) (mg/L)					
Arsenic	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Mercury	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Selenium	<0.0040	<0.0040	<0.0050	<0.0040	<0.0040
Thallium	<0.0020	<0.0020	<0.0020	<0.0010	<0.0020
Metals (ICPES) (mg/L)					
Aluminum	0.57	0.57	0.53	0.50	0.70
Barium	0.32	0.35	0.37	0.39	0.40
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Cadmium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Calcium	93	95	98	93	88
Chromium	<0.030	<0.030	<0.030	<0.030	<0.030
Copper	<0.020	<0.020	<0.020	<0.020	<0.020
Lead	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel	<0.020	<0.020	<0.020	<0.020	<0.020
Sodium	17	11	9.8	12	16
Zinc	<0.020	<0.020	0.037	<0.020	<0.020
Other Chemical Tests					
Eh (mV)	-24	-22	-33	-52	-62
Filterable Residue (TDS) (mg/L)	380	310	340	350	340
Oil & Grease, infrared (mg/L)	<0.40	<0.40	<0.40	<0.50	<0.40
pH (pH units)	11.1	11.1	11.2	10.9	11.3
Total Organic Carbon (mg/L)	6.3	5.3	5.3	5.3	6.0



Figure C-2. Closely Formed Stack of Treated Waste Monoliths

Table C-12. Chemical Analyses of ANS 16.1 Leachate from Treated Off-Site Area One Waste

	DAY 1	DAY 3	DAY 7	DAY 14	DAY 28
PCBs (µg/L)					
Aroclor-1242	<0.21	<0.21	<0.11	<0.020	<0.11
Aroclor-1260	<0.42	<0.42	<0.22	<0.040	<0.22
Metals (AA) (mg/L)					
Arsenic	0.0070	0.0053	0.0063	0.0063	0.0080
Mercury	<0.00020	<0.00020	<0.00020	<0.00030	<0.00020
Selenium	<0.0040	<0.0040	<0.0050	<0.0040	<0.0040
Thallium	<0.0020	<0.0020	<0.0020	<0.0010	<0.0020
Metals (ICPES) (mg/L)					
Aluminum	<0.20	0.30	0.37	0.43	0.73
Barium	0.33	0.42	0.54	0.67	0.90
Beryllium	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Cadmium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Calcium	110	130	150	170	220
Chromium	<0.030	<0.030	<0.030	<0.030	<0.030
Copper	<0.020	<0.020	<0.020	<0.020	<0.020
Lead	<0.050	<0.050	<0.050	<0.050	<0.050
Nickel	<0.020	<0.020	<0.020	<0.020	<0.020
Sodium	17	11	9.9	11	13
Zinc	<0.020	<0.020	<0.020	<0.020	<0.020
Other Chemical Tests					
Eh (mV)	-32	-28	-48	-67	-78
Filterable Residue (TDS) (mg/L)	610	570	620	740	870
Oil & Grease, infrared (mg/L)	1.9	1.7	1.9	1.1	3.2
pH (pH units)	11.1	11.4	11.4	11.1	11.7
Total Organic Carbon (mg/L)	13	11	13	11	20

Table C-13. WILT Test Results Through Week 28

Parameter	Off-Site Area One		Filter Cake		Filter Cake/ Oily Sludge	
	Column		Column		Column	
	Small	Large	Small	Large	Small	Large
PCBs ^a (µg/cm ²)	ND ^b	ND	ND	ND	ND	ND
Metals ^a (µg/cm ²)						
Aluminum	19	47	24	32	34	53
Calcium	5500	2100	3600	4000	1900	1400
Sodium	1100	1100	620	890	1100	1100
Lead	ND	0.04	0.09	0.13	ND	0.27
TOC ^a (µg/cm ²)	NC ^c	770	NC	610	NC	200
TDS ^a (mg/cm ²)	NC	20	NC	23	NC	9.4
pH ^d	11.9	11.6	11.4	11.3	11.7	11.4

Notes:

- a Cumulative amount leached from cylinders over 28 weeks is expressed as mass per cm² of cylinder surface area. The small cylinders are 3 inches in diameter and 18 inches in height. The large cylinders are 6 inches in diameter and 18 inches in height.
- b Not detected.
- c Not calculable.
- d The pH value represents the average pH over the length of the 28 week test.

Overall Demonstration Schedule

The overall demonstration schedule allowed one day for mobilization of the Soliditech equipment three days for waste treatment, and one day for demobilization of the Soliditech equipment. Due to delays in the collection of the waste material and the minor electrical problem, waste treatment did not start until the end of the second day. All waste treatment runs were completed on schedule. The Soliditech equipment was demobilized on schedule. Site preparation required three days and site demobilization required four days after the equipment was removed.

References for Appendix C

- U.S. EPA, 1986. Prohibition on the Placement of Bulk Liquid Hazardous Waste in Landfills, Statutory Interpretative Guidance. EPA/530/SW86/016, 1986.
- U.S. EPA, 1990. Technology Evaluation Report, SITE Program Demonstration Test, Soliditech, Inc. Solidification/Stabilization **Process**. U.S. EPA, RREL, Cincinnati, Ohio, EPA/540/5-89/005a, February 1990.

Appendix D

Case Studies

[This appendix was prepared by the developer, Soliditech, Inc. according to guidance provided by U.S. EPA.]

Soliditech has only recently initiated the commercial development phase. Although extensive research and development programs have been conducted, they have no extensive history of commercial projects. However, the process equipment and solidification technology have been used by Soliditech's subcontractor, Malone Service Company, on a variety of projects. The nature and scale of these projects are described below.

Remediation of Site Contaminated with Oil Field Chemicals

This project consisted of the solidification of approximately 3,000 drums of sand, top soil, clay **and** rock from the west Texas area (Odessa) contaminated with oilfield chemicals (primarily amines). Mobilization to the site was approximately 400 miles. Preparation at the site included constructing and lining (with PVC) a small pad used for the mixing equipment and for discharging the treated waste from the mixer. A specially equipped front-end loader for drum handling was used to transport the drummed waste from the holding area to the mixing unit. Other equipment used included the 10-cubic yard mixer, the pozzolan silo (kiln dust), a drum crusher and a 2 to 4 inch grating over the mixer to screen out large objects. The site owner disposed of the treated waste and handled negotiations and arrangements with state regulatory authorities.

The project required two full-time equipment operators on-site and was completed in approximately three and one-half weeks. Although minor equipment maintenance was required, the mixing and solidification process was completed without incident. The project was conducted on a day-rate basis because of the variables introduced by handling materials packaged in drums. All-inclusive billable project costs were approximately \$850 per day.

Monthly Chemical Industry Servicing

This is an ongoing service contract to stabilize drainage sump material containing various organic chemicals, such as

styrene, benzene, and oxy-alcohol; and heavy metals, such as mercury and chrome. The solidification is conducted using the 10-cubic yard mixer mounted on a low-boy trailer and an additional trailer to transport 85 gallon drums of pozzolan (fly ash). The fly ash is transferred into the mixer using a drum-handling device. Each service job requires approximately six to eight hours, because the waste is transferred into the mixer by the client's personnel because of plant policies. The treated material is discharged into one or more 20-yard roll-off containers, where it is allowed to cure for one to four days prior to disposal at an appropriate landfill facility.

Remediation of Superfund Site - PCB Contaminated Soil

This project consisted of processing approximately 1,200 severely deteriorated drums of soil and clay contaminated with 500 parts per million (ppm) of polychlorinated biphenyls (PCBs). The drums had been stored uncovered on unprotected ground and had become damaged to the degree that normal drum handling procedures were ineffective. Drums had to be manually removed from contents and manually lifted onto the forklifts. This required five field technicians (including operators) for approximately three weeks. Equipment used included the 10-cubic yard mixer, pozzolan silo (fly ash), a front-end loader, drum crusher, two forklifts (one all-terrain), one backhoe (John Deere 690), and roll-off containers for receiving treated waste discharge.

The above-described projects illustrate that waste handling and transport to the mixer are among the most significant factors determining the time and cost required for field service remediation projects. As such, jobs are typically costed on a day-rate basis.

These examples, although limited, demonstrated that the process is applicable to containerized waste as well as waste streams in bulk form. The process can be applied effectively and economically in a variety of settings.